1.List of data, formulae and relationships

Data

Gravitational constant	$G = 6.67 \times 10^{-11}\, Nm^2 kg^{-2}$	
Acceleration of free fall	$g = 9.81\, m\, s^{-2}$	(close to the Earth)
Gravitational field strength	$g - 9.81\, N\ kg^{-1}$	(close to the Earth)
Electronic charge	$e = -1.60 \times 10^{-19}\, C$	
Electronic mass	$m_e = 9.11 \times 10^{-31}\, kg$	
Unified mass unit	$u = 1.66 \times 10^{-27}\, kg$	
Planck constant	$h = 6.63 \times 10^{-34}\, J\, s$	
Speed of light in vacuum	$c = 3.00 \times 10^{8}\ m\, s^{-1}$	
Molar gas constant	$R = 8.31\ J\ K^{-1}\ mol^{-1}$	
Boltzmann constant	$k = 1.38 \times 10^{-23}\, J\ K^{-1}$	
Avogadro constant	$N_a = 6.02 \times 10^{23}\ mol^{-1}$	
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\, Fm^{-1}$	
Permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\, N\ A^{-2}$	

Experimental physics

Percentage uncertainty $= \dfrac{\text{Estimated uncertainty}}{\text{Average value}} \times 100\%$

Mechanics

Force $F = \dfrac{\Delta p}{\Delta t}$

For uniformly accelerated motion:

$v = u + at$

$x = ut + ½\, at^2$

$v^2 = + 2ax$

Work done or energy transferred $\Delta W = \Delta E = p\Delta V$ (Presssure p; Volume V)

Power P = Fv

Angular speed $\omega = \dfrac{\Delta\theta}{\Delta t} = \dfrac{v}{r}$ (Radius of circular path r)

Period $T = \dfrac{1}{f} = \dfrac{2\pi}{\omega}$ (Frequency f)

Radial acceleration $a = r\omega^2 = \dfrac{v^2}{r}$

Couple (due to a pair of forces F and $-F$)

= F × (Perpendicular distance from F to $-F$)

Electricity

Electric current	$I = nAQv$(Number of charge carriers per unit volume n)	
Electric power	$P = I^2R$	
Resistors in series	$R = R_1 + R_2 + R_3$	
Resistors in parallel	$R_\theta = R_0(1 + \alpha\theta)$	(Temperature coefficient α)
Resistance at temperature θ	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$	
Capacitance of parallel plates	$C = \frac{\varepsilon_0 \varepsilon_1 A}{d}$	
Capacitors in parallel	$C = C_1 + C_2 + C_3$	
Capacitors in series	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$	
Energy stored	$W = \frac{1}{2}CV^2$	

Nuclear physics

Mass-energy	$\Delta E = c^2 \Delta m$	
Radioactive decay rate	$\frac{dN}{dt} = -\lambda N$	(Decay constant λ)
	$N = N_0 e^{-\lambda t}$	
Half-life	$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$	
Photon model	$E = hf$	
Energy levels	$hf = E_1 - E_2$	
de Broglie wavelength	$\lambda = \frac{h}{p}$	

Matter and materials

Density	$\rho = \frac{m}{V}$	
Hooke's law	$F = k\Delta x$	
Stress	$\sigma = \frac{F}{A}$	
Strain	$\varepsilon = \frac{\Delta l}{l}$	
Young modules	$E = \frac{Stress}{Strain}$	
Work done in stretching	$\Delta W = ½F\Delta x$	(provided Hooke's law holds)

Oscillations and waves

For a simple pendulum $T = 2\pi\sqrt{\frac{l}{g}}$

For a mass on a spring $T = 2\pi\sqrt{\frac{m}{k}}$

At distance *r* from a point source of power *P*, intensity $I = \frac{P}{4\pi r^2}$

For Young's slits, of slit seperation *s*, wavelength $\lambda = \frac{xs}{D}$

(Fringe width *x*; slits to screen distance *D*)

Refraction $\frac{\sin\theta_1}{\sin\theta_2} = \frac{\lambda_1}{\lambda_2} = \frac{c_1}{c_2} = \frac{n_2}{n_1}$ (Refractive index *n*)

$\sin\theta_c = \frac{c_1}{c_2}$ (Critical angle θ_c)

$n_1 = \frac{c}{c_1}$

Quantum phenomena

Maximum energy temperature $= hf - \varphi$ (Work function φ)

Thermal physics

Celcius temperature $\theta/°C = T/K - 273.15$

Practical Celsius scale $\theta = \frac{X_\theta - X_0}{X_{100} - X_0} \times 100\,°C$

Thermal energy transfer $\Delta Q = mc\Delta T$ (Specific heat capacity *c*; temperature change ΔT)

Change of internal energy $\Delta U = \Delta Q + \Delta W$ (Work done on body ΔW)

Thermal energy transferred on change of state $= l\Delta m$

(Specific latent heat or specific enthalpy change *l*)

Rate of thermal energy transfer by conduction $= kA\dfrac{\Delta T}{\Delta x}$

(Thermal conductivity k; temperature gradient $\dfrac{\Delta T}{\Delta x}$)

Kinetic theory $pV = \frac{1}{3} Nm(c^2)$

$T \propto$ *Average kinetic energy of molecules*

Mean kinetic energy of molecules $= 3/2\, kT$ (Boltzmann constant k)

Molar gas constant $R = kN_A$ (Avogadro constant N_A)

Upthrust U = Weight of displaced fluid

Pressure difference in fluid $\Delta p = \rho g \Delta h$

Fields

Electric field strength

uniform field $E = F/Q = V/d$

radial field $E = kQ/r^2$ (Where for free space or air $k = 1/4\pi\varepsilon_0$)

Electric potential

radial field $V = kQ/r$

For an electron in a vacuum tube $e\Delta V = \Delta(1/2\, mv^2)$

Gravitational field strength

radial field $g = GM/r^2$

Gravitational potential

radial field $V = -GM/r$, numerically

Time constant for capacitor charge or discharge = RC

Force on a wire $F = Bil$

Force on a moving charge $F = BQv$

Field inside a long solenoid $= \mu_0 nI$ (Number of turns per metre n)

Field near a long straight wire $= \dfrac{\mu_0 I}{2\pi r}$

E.m.f. induced in a moving conductor $= Blv$

Flux $\Phi = BA$

E.m.f. induced in a coil $= \dfrac{Nd\Phi}{dt}$ (Number of turns N)

For $I = I_0 \sin 2\pi ft$ *and* $V = V_0 \sin 2\pi ft$:

$$I_{\text{rms}} = \frac{I_0}{\sqrt{2}} \text{ and } V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$$

$$\text{Mean power} = I_{\text{rms}} \times V_{\text{rms}} = \frac{I_0 V_0}{2}$$

Mathematics

	$\sin(90° - \theta)$	$= \cos\theta$
	$\ln(x^n)$	$= n \ln x$
	$\ln(e^{kx})$	$= kx$
Equation of a straight line	y	$= mx + c$
Surface area	cylinder	$= 2\pi rh + 2\pi r^2$
	sphere	$= 4\pi r^2$
Volume	cylinder	$= \pi r^2 h$
	sphere	$= {}^4/_3\, \pi r^3$
For small angles:	$\sin\theta$	$\approx \tan\theta \approx \theta$ (in radians)
	$\cos\theta$	≈ 1

2. The list gives some quantities and units. *Underline* those which are base quantities of the International (SI) System of units.

coulomb force length mole newton temperature interval

(2)

Define the volt.

....

....

(2)

Use your definition to express the volt in terms of base units.

....

....

....

(3)

Explain the difference between scalar and vector quantities.

....

....

....

(2)

Is potential difference a scalar or vector quantity?

....

(1)

(Total 10 marks)

3. A cell of negligible internal resistance is connected in series with a microammeter of negligible resistance and two resistors of 10 kΩ and 15 kΩ. The current is 200 μA.

Draw a circuit diagram of the arrangement.

(1)

Calculate the e.m.f. of the cell.

....

....

e.m.f. = ...

(2)

Where a voltmeter is connected in parallel with the 15 kΩ resistor, the current in the microammeter increases to 250 μA. Sketch a diagram of the modified circuit.

(1)

Calculate the resistance of the voltmeter.

....

....

....

....

Resistance = ...

(3)
(Total 7 marks)

4. A copper wire is 2.0 m long and has a cross-sectional area of 1.00 mm^2. It has a p.d. of 0.12 V across it when the current in it is 3.5 A. Draw a circuit diagram to show how you would check these voltage and current values.

(3)

Calculate the rate at which the power supply does work on the wire.

....

....

Rate = ...

(2)

Copper has about 1.7×10^{29} electrons per metre cubed. Calculate the drift speed of the charge carriers in the wire.

....

....

....

Drift speed = ...

(3)

The power from the supply connected to the wire is equal to the total force F_t on the electrons multiplied by the drift speed at which the electrons travel. Calculate F_t.

....

....

....

F_t = ...

(3)
(Total 11 marks)

5. A light-dependent resistor may be used with additional components to make a light meter. Sketch a diagram for a suitable circuit.

(2)

Explain how your circuit works

....

....

....

....

(2)
(Total 4 marks)

6. A 24 W filament lamp has been switched on for some time. In this situation the first law of thermodynamics, represented by the equation $\Delta U = \Delta Q + \Delta W$, may be applied to the lamp. State and explain the value of each of the terms in the equation during a period of *two* seconds of the lamp's operation.

ΔU ....

....

....

(2)

ΔW ....

....

....

(2)

ΔQ ....

....

....

(2)

Typically, filament lamps have an efficiency of only a few percent. Explain what this means and how it is consistent with the law of conservation of energy.

....

....

....

(2)

(Total 8 marks)

7. The energy for a pendulum (long case) clock is stored as gravitational potential energy in a heavy brass cylinder. As the cylinder descends its energy is gradually transferred to a steel pendulum to keep it swinging with a constant amplitude.

(a) In one clock the brass cylinder has a mass of 5.6 kg.

(i) The cylinder descends 1.4 m in seven days. What is the power transfer during its descent?

(ii) In an accident the brass cylinder suddenly fell 1.4 m to the ground. Estimate by how much its temperature would rise. State any assumption you make.

(Take the specific heat capacity of brass to be 360 J kg^{-1} K^{-1}.)

(6)

(b) The pendulum swings in an East-West plane with a time period of 2.00 s.

(i) Explain why a potential difference will be induced between the top and the bottom of the steel pendulum.

(ii) Sketch a graph to show the variation of this induced p.d. with time. Add a scale to your time axis.

(6)

(c) It is suggested that the induced p.d. described in (b) could be used to energise an electromagnet. This could then be placed so as to attract the steel pendulum during part of each swing and thus do away with the need for the brass cylinder.

Discuss this suggestion, concentrating on the physical principles involved.

(4)

(Total 16 marks)

8. With the aid of an example, explain the statement "The magnitude of a physical quantity is written as the product of a number and a unit".

....

....

....

....

(2)

Explain why an equation must be homogeneous with respect to the units if it is to be correct.

....

....

....

....

....

(1)

Write down an equation which is homogeneous, but still incorrect.

....

....

(2)

9. Define the term *resistivity.*

....

....

....

(2)

The resistivity of copper is 1.7×10^{-8} Ωm. A copper wire is 0.6 m long and has a cross-sectional area of $1 mm^2$. Calculate its resistance.

....

....

....

Resistance = ...

(3)

Two such wires as used to connect a lamp to a power supply of negligible internal resistance. The potential difference across the lamp is 12 V and its power is 36 W. Calculate the potential difference across each wire.

....

....

....

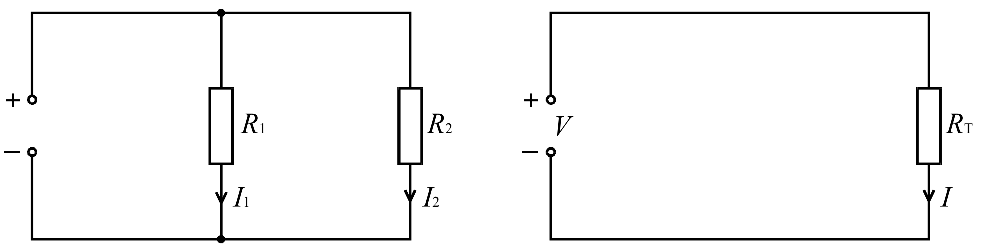
Potential difference = ...

(3)

Draw a circuit diagram of the above arrangement. Label the potential differences across the wires, lamp and power supply.

(3)
(Total 11 marks)

10. The power supplies in the two circuits shown below are identical.



Write down the relationship between I_1, I_2 and I which must hold if the combined resistance of the parallel pair, R_1, and R_2, is to equal R_r.

....

....

(1)

Hence derive the formula for the equivalent resistance of two resistors connected in parallel.

....

....

....

....

....

(3)

Use your formula to show that the resistance between the terminals of a low-resistance component is hardly changed when a high-resistance voltmeter is connected in parallel with it.

....

....

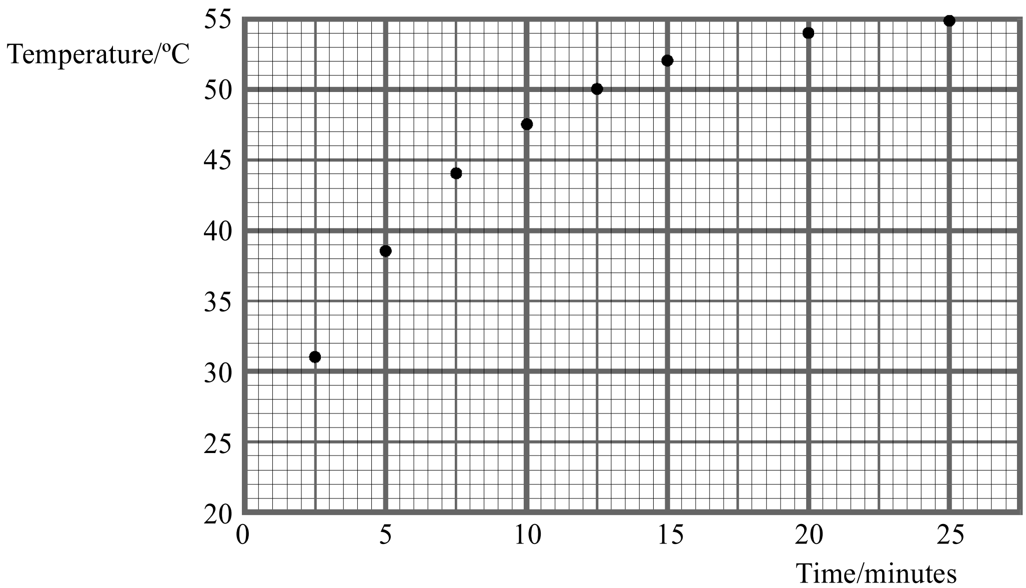
....

....

....

(2)
(Total 6 marks)

11. A student pours 500 g of water into an aluminium saucepan of mass 1.20 kg, heats it over a steady flame and records the temperature as it heats up. The temperatures are plotted as shown below.



Calculate the total heat capacity of the saucepan and water.

Specific heat capacity of water = 4200 J kg^{-1} K^{-1}
Specific heat capacity of aluminium = 900 J kg^{-1} K^{-1}

....

....

....

Heat capacity = ...

(3)

Find the rate of rise of water temperature at the beginning of the heating process.

....

....

Rate of rise of temperature = ...

(2)

Hence find the rate at which energy is supplied to the saucepan and water.

....

....

Rate of energy supply = ...

(2)

Explain why the rate at which the temperature rises slows down progressively as the heating process continues.

....

....

....

....

(2)
(Total 9 marks)

12. The relationship pV = constant applies to a sample of gases provided that two other physical variables are constant. Name them.

First variable ....

Second variable ....

(2)

With the aid of a diagram, describe carefully how you would test the relationship by experiment.

....

....

....

....

....

....

(6)
(Total 8 marks)

13. Read the passage carefully and then answer the questions at the end.

What is Lightning?

Lightning has been a source of wonder to all generations. Its origins, in the processes of the electrification of thunderstorms, are being studied by means of laboratory experiments, together with observational and theoretical studies.

Summer airmass storms and winter-time cold frontal storms can become electrified and produce lightning and thunder. The high currents in the lightning strokes (typically 20 000 A) heat the air sufficiently to cause rapid expansion; the resulting shock wave is heard as thunder. Travelling at the speed of sound, 340 m/s', the noise arrives after the flash is seen and so the distance to the storm may be estimated. The flash is seen as a result of the effect of the electrical discharge on the gases through which the discharge travels. The lightning may occur completely within the cloud as a cloud stroke, often called sheet lightning, or it may reach the Earth as a ground stroke.

In the production of a ground stroke, the lightning channel first makes its way towards the ground as a weakly luminous negative leader which attracts positive charge from sharp objects on the ground. This leader is a column of negatively charged ions which flow from the charged lower regions of the cloud in a stepwise fashion to form a conducting channel between the cloud and the ground. When a conducting channel is completed the negative charge flows to ground. The brightest part of the channel appears to move upwards at about 30% of the speed of light. Often there is sufficient charge available to allow several strokes to occur along the same lightning channel within a very short time. The resulting flickering can be observed by the eye and the whole series of strokes is called a flash. The peak electrical power is typically 1×10^8 W per metre of channel, most of which is dissipated in heating the channel to around 30 000 °C.

In London the average number of days per year on which thunder is heard is 17, the peak thunderstorm activity being in the late afternoon and evening during Summer. When a person is struck by lightning, heart action and breathing stop immediately. Heart action usually starts again spontaneously but breathing may not and, on average, four people are killed by lightning each year in Britain.

(a) Explain how the distance from an observer to a lightning flash may be estimated. Illustrate this for the case where the distance is 1.5 km.

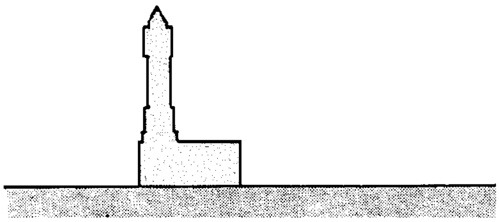
(3)

(b) Explain the meaning of the phrase *sheet lightning* (paragraph 2).

Use the passage to explain how thunder is produced.

(5)

(c) The diagram represents a storm cloud over a building with a high clock tower.



Copy the diagram. Explain, with the aid of additions to your diagram, what is meant by a *negative leader* (paragraph 3).

(4)

(d) Describe the process by which a lightning stroke produces visible light.

Explain why, when you see a lightning flash, it may seem to flicker.

(5)

(e) Suppose lightning strikes from a cloud to the Earth along a channel 400 m long.

Calculate

(i) a typical potential difference between cloud and Earth,

(ii) the average electric field strength along such a lightning channel.

(6)

(f) Describe how you would attempt to demonstrate in the laboratory that the electric field strength needed to produce a spark in air is about 3000 V mm^{-1} (3×10^6 V m^{-1}). Suggest why this value differs from that which you calculated in (*e*).

(4)

(g) Estimate the pressure of the air within a lightning channel immediately after a lightning flash. Take the atmospheric pressure to be 100 kPa. State any assumptions you make.

(5)
(Total 32 marks)

14. (a) Describe briefly how you would determine a value for the *specific heat capacity c* of water using normal laboratory apparatus.

(4)

(b) A jogger of mass 75 kg, who runs for 30 minutes, generates 840 kJ of thermal energy.

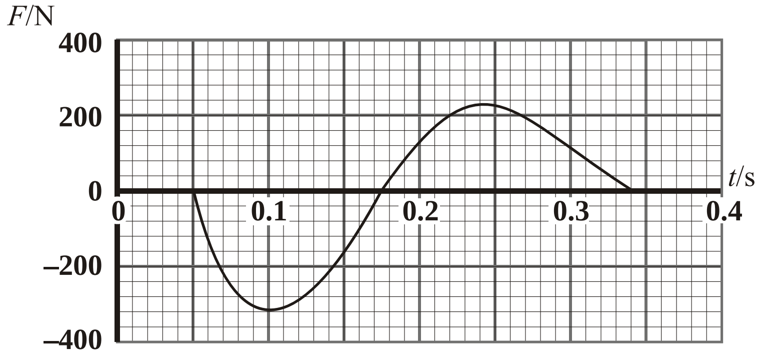
(i) Explain, in molecular terms, the way in which the removal of some of this energy by evaporation can help to prevent the jogger's body temperature from rising.

(3)

If 40% of the thermal energy is removed by evaporation, calculate the mass of water evaporating during the 30 minute jog. Take the specific latent heat (enthalpy) of vaporisation of water to be 2260 kJ kg^{-1} and the density of water to be 1000 kg m^{-3}

(3)

(c) During a single stride the *horizontal push F* of the ground on the jogger's foot varies with time *t* approximately as shown in the graph. *F* is taken to be positive when it is in the direction of the jogger's motion.



(i) What physical quantity is represented by the area between the graph line and the time axis?

Estimate the size of this quantity for the part of the graph for which *F* is positive. Explain how you made your estimate.

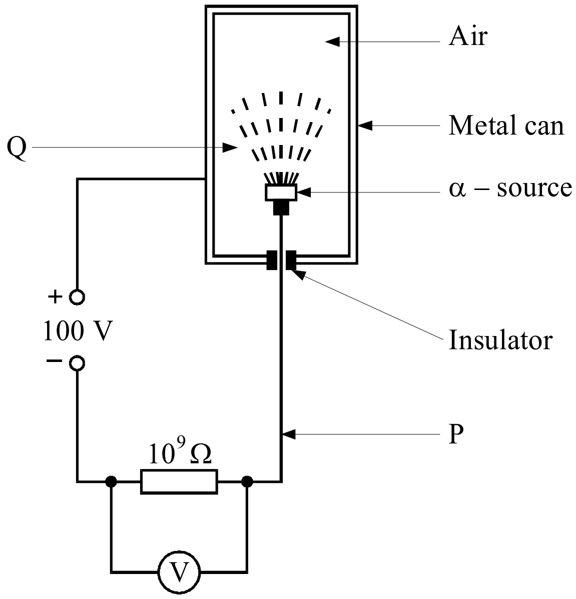
(4)

(ii) The area above the time axis is the same as the area below it. Explain what this tells you about the motion of the jogger.

(2)

(Total 16 marks)

15. An α-source with an activity of 150 kBq is placed in a metal can as shown. A 100 V d.c. source and a $10^9\ \Omega$ resistor are connected in series with the can and the source. This arrangement is sometimes called an ionisation chamber.



(a) What is meant in this case by *an activity of 150 kBq*?

(2)

(b) Describe how the nature of the electric current in the wire at P differs from that in the air at Q.

(3)

(c) A potential difference of 3.4 V is registered on the voltmeter.

(i) Calculate the current in the wire at P. State any assumption you make.

(ii) Calculate the corresponding number of ionisations occurring in the metal can every second. State any assumption you make.

(5)

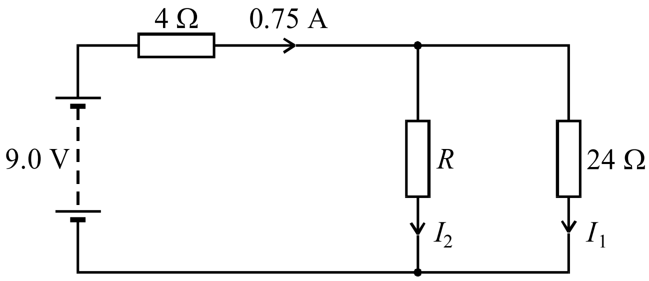
(d) With the α-source removed from the metal can, the voltmeter still registers a potential difference of 0.2 V. Suggest two reasons why the current is not zero.

(2)

(e) The half-life of the α-source is known to be 1600 years. Calculate the decay constant and hence deduce the number of radioactive atoms in the source.

(4)
(Total 16 marks)

16. The circuit shows a battery of negligible internal resistance connected to three resistors.



Calculate current I_1.

....

....

....

I_1 = ...

(3)

Calculate resistance *R*

....

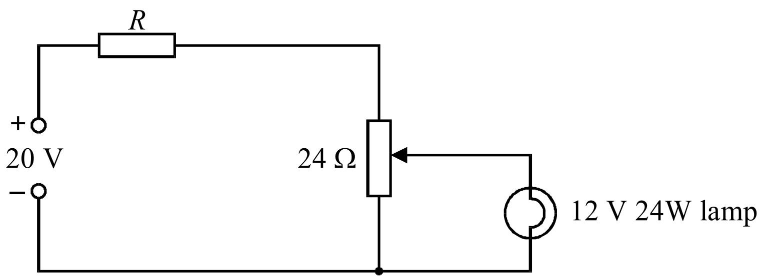
....

R = ...

(2)

(Total 5 marks)

17. The circuit shown is used to produce a current-voltage graph for a 12 V, 24 W lamp.



Show on the diagram the correct position for a voltmeter and an ammeter.

(2)

Calculate the resistance of the lamp in normal operation.

....

....

....

Resistance = ...

(3)

Calculate the value for *R* which would enable the voltage across the lamp to be varied between 0 V and 12V.

....

....

....

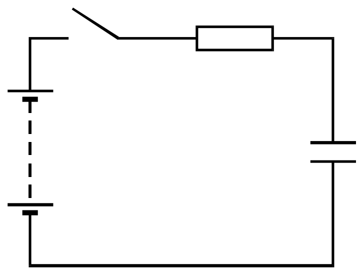
....

R = ...

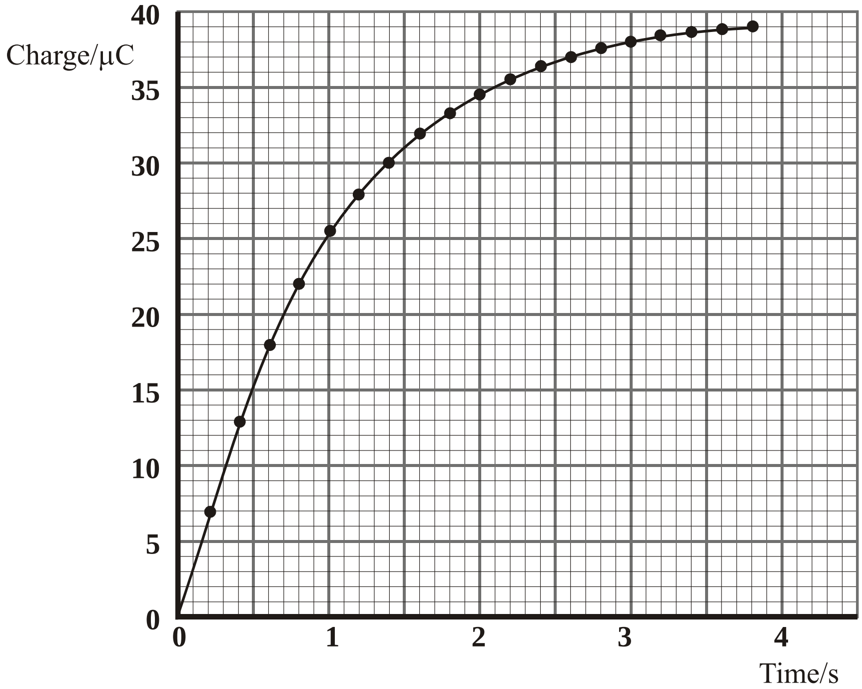
(4)

(Total 9 marks)

18. The circuit shown is used to charge a capacitor.



The graph shows the charge stored on the capacitor whilst it is being charged.



On the same axes, sketch as accurately as you can a graph of current against time.
Label the current axis with an appropriate scale.

(4)

The power supply is 3 V. Calculate the resistance of the charging circuit.

....

....

Resistance = ...

(2)
(Total 6 marks)

19. A mass is oscillating vertically on the end of a spring. Explain what happens to the following quantities as the mass rises from the bottom of its motion to the top.

Kinetic energy

....

....

....

Gravitational potential energy

....

....

....

Elastic potential energy

....

....

....

(4)

After a long time, the mass stops oscillating. What has happened to the energy?

....

....

....

(2)
(Total 6 marks)

20. What is meant by a *heat engine?*

....

....

....

....

....

(3)

Explain why there is a constant search for materials to make turbine blades that will operate at higher temperatures to improve the efficiency of thermal power stations.

....

....

....

....

....

(2)
(Total 5 marks)

21. The permittivity of free space ε_0 has units F m^{-1}. The permeability of free space μ_0 has units N A^{-2}

Show that the units of $\dfrac{1}{\sqrt{\varepsilon_0 \mu_0}}$ are m s^{-1}

....

....

....

....

....

....

(3)

Calculate the magnitude of $\dfrac{1}{\sqrt{\varepsilon_0 \mu_0}}$.

....

....

Magnitude = ...

(1)

Comment on your answers.

....

....

(1)

(Total 5 marks)

22. For each of the four concepts listed in the left hand column, place a tick by the correct example of that concept in the appropriate box.

A base quantity	mole	☐	length	☐	kilogram	☐
A base unit	coulomb	☐	ampere	☐	volt	☐
A scalar quantity	torque	☐	velocity	☐	kinetic energy	☐
A vector quantity	mass	☐	weight	☐	density	☐

(Total 4 marks)

23. You are asked to measure the specific heat capacity of aluminium using a cylindrical block of aluminium which has been drilled out to accept an electrical heater.

Draw a complete diagram of the apparatus you would use.

(3)

Describe how you would carry out the experiment and list the measurements you would take.

....

....

....

....

....

....

(5)

Explain how you would calculate the specific heat capacity of aluminium from your measurements.

....

....

....

....

(3)
(Total 11 marks)

24. Describe the concept of the heat engine.

....

....

....

....

....

(3)

Define the term “efficiency” used in connection with heat engines.

....

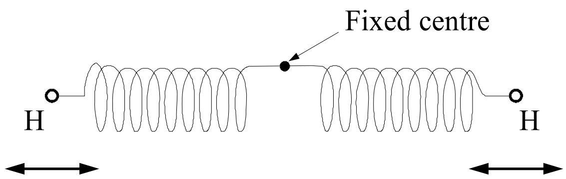
....

....

....

(2)
(Total 5 marks)

25. One simple model of the hydrogen molecule assumes that it is composed of two oscillating hydrogen atoms joined by two springs as shown in the diagram.



If the spring constant of each spring is 1.13×10^{3} N m^{-1}, and the mass of a hydrogen atom is 1.67×10^{-27} kg, show that the frequency of oscillation of a hydrogen atom is 1.31×10^{14} Hz.

....

....

....

....

(2)

Using this spring model, discuss why light of wavelength 2.29×10^{-6} m would be strongly absorbed by the hydrogen molecule.

....

....

....

....

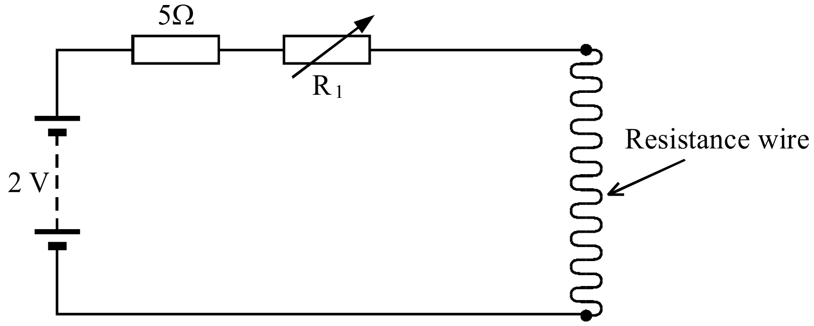
....

....

(4)
(Total 6 marks)

26. You are given a piece of resistance wire. It is between two and three metres long and has a resistance of about 15 Ω. You are asked to measure the resistivity of the metal alloy it is made from.

Make the necessary additions to the following circuit to enable it to be used for the experiment.



(2)

Describe briefly how you would use the circuit above to measure the resistance of the wire.

....

....

....

....

....

....

....

(5)

Once the resistance of the wire is known, two more quantities must be measured before its resistivity can be calculated. What are they?

....

....

....

....

(2)

Is there any advantage in finding the resistance of the wire from a graph compared with calculating an average value from the measurements? Explain your answer.

....

....

....

....

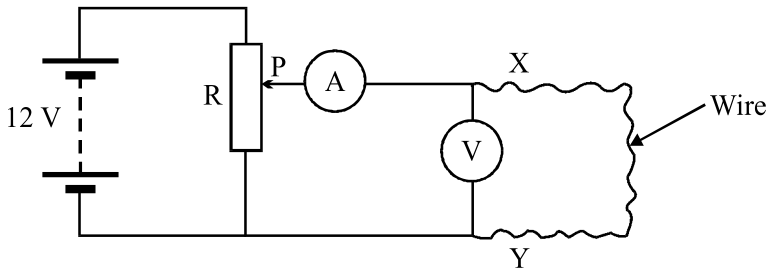
(2)
(Total 11 marks)

27. Classify each of the terms in the left-hand column by placing a tick in the relevant box.

	Base unit	**Derived unit**	**Base quantity**	**Derived quantity**
Length				
Kilogram				
Current				
Power				
Coulomb				
Joule				

(Total 6 marks)

28. The circuit diagram shows a 12 V power supply connected across a potential divider R by the sliding contact P. The potential divider is linked to a resistance wire XY through an ammeter. A voltmeter is connected across the wire XY.



Explain, with reference to this circuit, the term *potential divider*.

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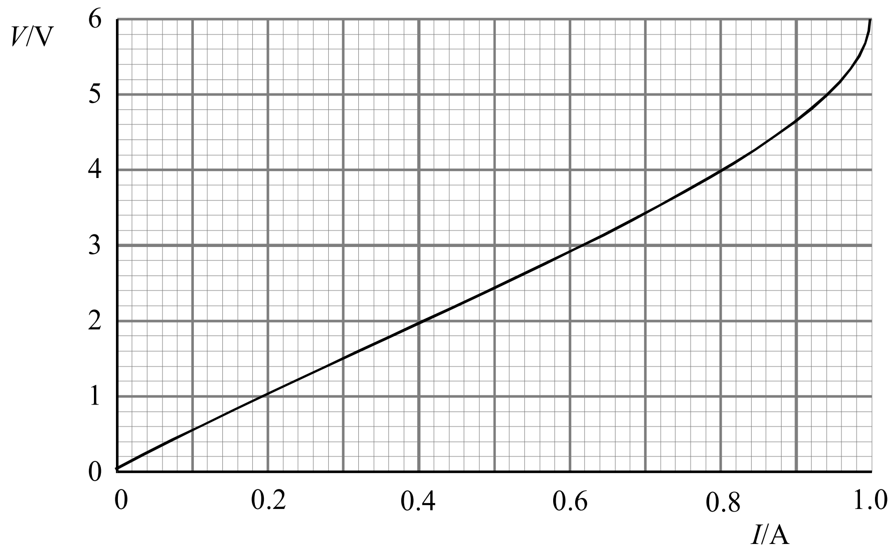
(2)

The circuit has been set up to measure the resistance of the wire XY. A set of voltage and current measurements is recorded and used to draw the following graph.



Explain why the curve deviates from a straight line at higher current values.

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…………………………………………………………………………………………………

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…………………………………………………………………………………………………

(2)

Calculate the resistance of the wire for low current values.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(2)

To determine the resistivity of the material of the wire, two more quantities would have to be measured. What are they?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(2)

Explain which of these two measurements you would expect to have the greater influence on the error in a calculated value for the resistivity? How would you minimise this error?

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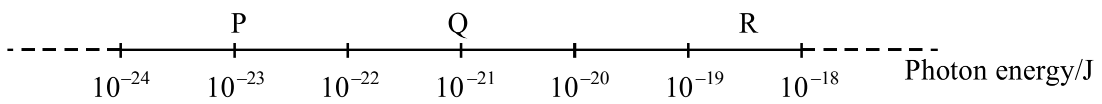
(3)
(Total 11 marks)

29. The diagram shows a range of photon energies which could be used to describe part of the electromagnetic spectrum.



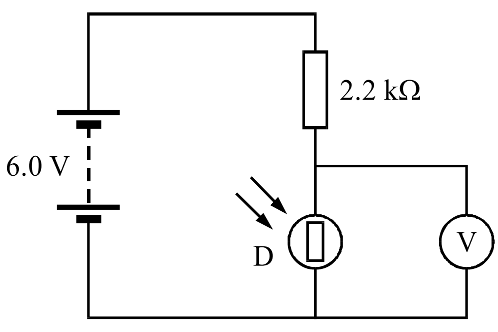
(a) Use information from the data sheet to identify the region of the spectrum labelled P. Name the regions labelled by Q and by R.

(4)

(b) Outline an experiment which would enable you to determine the wavelength of electromagnetic waves of wavelength about 30mm. Explain how the wavelength is calculated from the measurements you take.

(5)

(c) A beam of light is incident on a detector D whose resistance varies with the intensity of the light. The detector is connected in an electrical circuit as shown.



(i) At high illumination, the voltmeter registers 1.2 V. What is then the resistance of D? State any assumption you make.

(4)

(ii) At low illumination, the voltmeter registers 6.0 V, the same as it would record if connected directly across the cells.

What would you now do, using ordinary laboratory apparatus other than an ohmmeter, to find the resistance of D? Explain your answer.

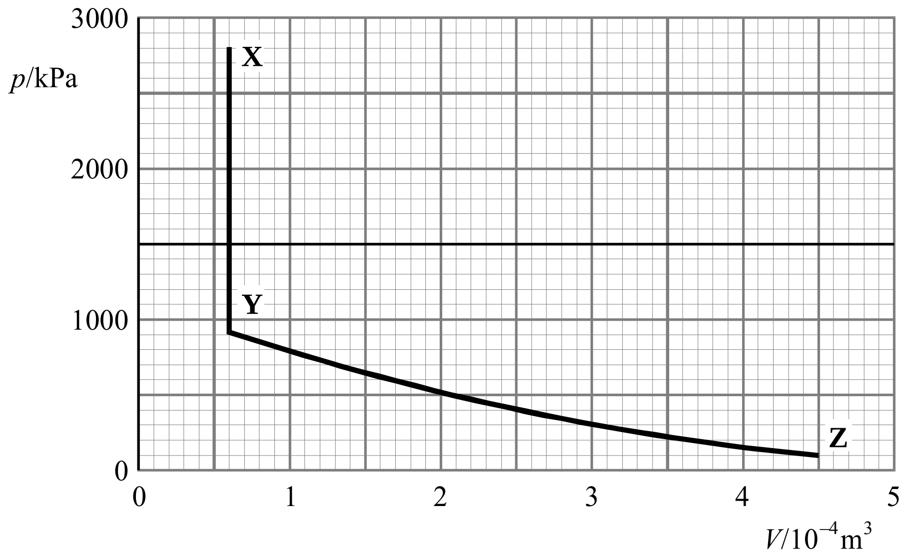
(3)
(Total 16 marks)

30. (a) Draw a labelled diagram of the apparatus you would use to demonstrate that the pressure *P* of an ideal gas is proportional to its absolute temperature *T*.

Do not describe the experiment, but state any precautions you would take during the measurements of *P* and *T*.

(5)

(b) In the cylinder of an ordinary petrol engine, air at atmospheric pressure is mixed with a little petrol vapour. The mixture, which behaves like an ideal gas, is then compressed. A spark ignites the mixture which causes it to be heated at a constant volume. The power stroke of the piston then follows. The *p*–*V* graph shows two of these three processes.



(i) The area beneath the curved part of the graph is 150 Pa m3. It represents the work done in compressing the gas. Show that the unit is equivalent to the joule.

(ii) If the temperature of the air-vapour mixture at Y is 640K, calculate the temperature in the cylinder at X. State any assumption you have made.

(6)

(c) Assume that the piston in a petrol engine moves with simple harmonic motion of amplitude 40 mm. Calculate the maximum acceleration of the piston when the engine is rotating at 8000 revolutions per minute.

The piston is connected to another part of the engine by a rod which is pulled and pushed as the piston moves inside the cylinder. Explain why the material from which the rod is made has to be carefully chosen.

(5)
(Total 16 marks)

31. A wire 6.00 m long has a resistivity of $1.72 ? 10^{-8}$? m and a cross-sectional area of 0.25 mm^2 Calculate the resistance of the wire.

....

....

....

Resistance = ...

(3)

The wire is made from copper. Copper has $1.10 ? 10^{29}$ free electrons per metre cubed. Calculate the current through the wire when the drift speed of the electrons is 0.093^{-1} mm s^{-1}.

....

....

....

Current = ...

(3)

The wire is cut in two and used to connect a lamp to a power supply. It takes 9 hours for an electron to travel from the power supply to the lamp. Explain why the lamp comes on almost as soon as the power supply is connected.

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....

....

(3)
(Total 9 marks)

32. A container holding 2.3 litres of milk at 15 °C is put into a freezer. Calculate the energy that must be removed from the milk to reduce its temperature to the freezer temperature of –30 °C. Assume that the milk behaves like ice and water.

Specific heat capacity of water = 4.2 kJ kg^{-1} K^{-1}
Specific heat capacity of ice 2.1 kJ kg^{-1} K^{-1}
Specific latent heat (enthalpy) of fusion of ice = 330 kJ kg^{-1}
Density of water = 1.0 kg $litre^{-1}$

....

....

....

Energy removed = ...

(6)

It costs 8.2 p per kWh to remove energy from the freezer. What is the cost of freezing the milk?

....

....

Cost = ...

(2)
(Total 8 marks)

33. The kinetic theory of gases is based on a number of assumptions. One assumption is that the average distance between the molecules is much larger than the molecular diameter. A second assumption is that the molecules are in continuous random motion. State and explain one observation in support of each assumption.

First assumption

....

....

....

....

Second assumption

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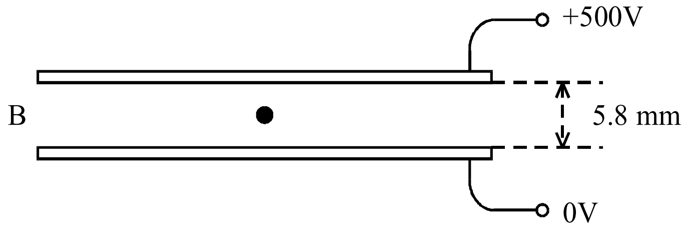
(Total 4 marks)

34. Lots of tiny plastic spheres are sprayed into the space between two horizontal plates which are electrically charged. After a time one sphere of mass 1.4×10^{-11}g is seen to be suspended at rest as shown.



(a) Explain how the sphere can be in equilibrium and calculate the charge on it.

Why must the plates be horizontal for the plastic spere to be at rest?

(6)

(b) A radioactive β-source is now placed at B for a short time and then removed. The plastic sphere is seen to move down at a steady speed.

Explain how the presence of the β-source has altered the charge on the sphere.

Draw a free-body force diagram of the sphere as it falls.

(3)

(c) Experiments of this kind confirm that *electric charge is quantised*.

Explain the meaning of the phrase in italics.

Name one other physical quantity which is quantised. Describe one situation where this quantum property is significant.

(4)

(d) The experiment above is repeated with plastic spheres which have a much smaller mass and using a lower potential difference between the plates. At no stage does any sphere appear to be completely at rest or to move steadily up or down. This agitated motion of the spheres is less noticeable when the temperature is considerably lowered.

Explain these observations.

(3)
(Total 16)

35. (a) In an oscilloscope, *N* electrons each of charge *e* hit the screen each second. Each electron is accelerated by a potential difference *V*.

(i) Write down an expression for the total energy of the electrons reaching the screen each second.

(ii) The power of the elctron beam is 2.4W. When the oscilloscope is first switched on the spot on the glass screen is found to rise in temperature by 85 K during the first 20 s.

The specific heat capacity of glass is 730 J $kg^{-1}K^{-1}$. Calculate the mass of glass heated by the electron beam. State two assumptions you have made in your calculation.

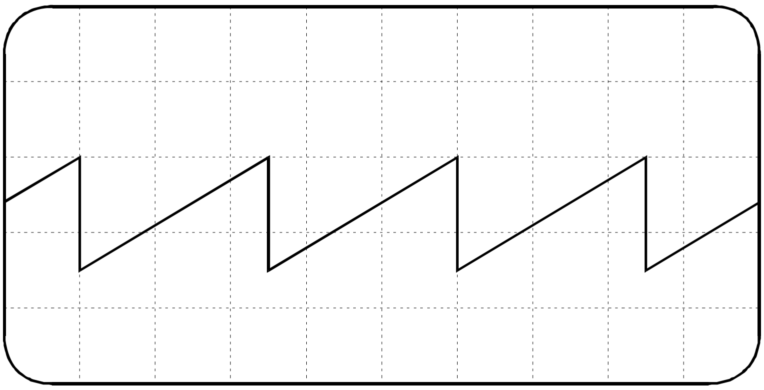
(7)

(b) Outline how, in principle, you would measure the specific heat capacity of glass. You may use a lump of glass of any convenient shape in your experiment.

What difficulties might lead to errors?

(5)

(c) The oscilloscope is now used to investigate the 'saw-toothed' signal from a signal generator. The trace show is obtained.



The Y-gain control is set at 0.2 volts per division and the time-based control at 100 microseconds per division.

(i) Calculate the frequency of the saw-toothed signal.

(ii) What is the rate of rise of the signal voltage during each cycle?

(4)
(Total 16)

36. A 100 W tungsten filament lamp operates from the 230 V mains. Calculate its resistance.

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Resistance =...

(2)

The drift speed of the electrons in the filament is much higher than the drift speed of electrons in the rest of the circuit. Suggest and explain a reason for this.

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....

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(4)
(Total 6 marks)

37. Each row in the following table starts with a term in the left hand column. Indicate with a tick which of the three expressions in the same row relates to the first term.

Joule	$kg\ m\ s^{-2}$	☐	$kg\ m\ s^{-2}$	☐	$kg\ m^2 s^{-3}$	☐
Coulomb	Base Unit	☐	Derived unit	☐	Base quantity	☐
Time	Scalar quantity	☐	Vector quantity	☐	Neither vector nor scalar	☐
Volt	A × W	☐	$A \times W^{-1}$	×	$W \times A^{-1}$	☐

(Total 4 marks)

38. Define the term *resistivity.*

....

....

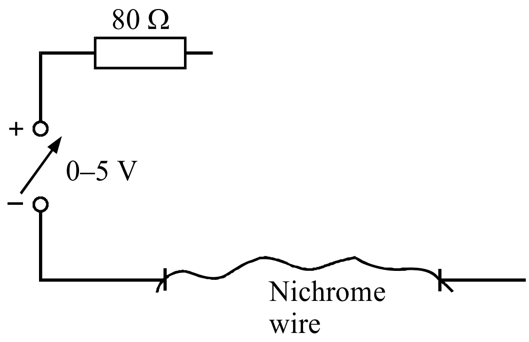
....

....

(2)

A student is asked to measure the resistivity of the alloy nichrome given a nichrome wire known to have a resistance of about two or three ohms. The wire is mounted between two copper clamps, X and Y, near the ends of the wire. The power supply is a variable power supply of output 0–5 V. The series resistor is 80 Ω.

Complete the following circuit diagram.



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(2)

The 80 Ω series resistor ensures that the current is kept small. Explain why this is important.

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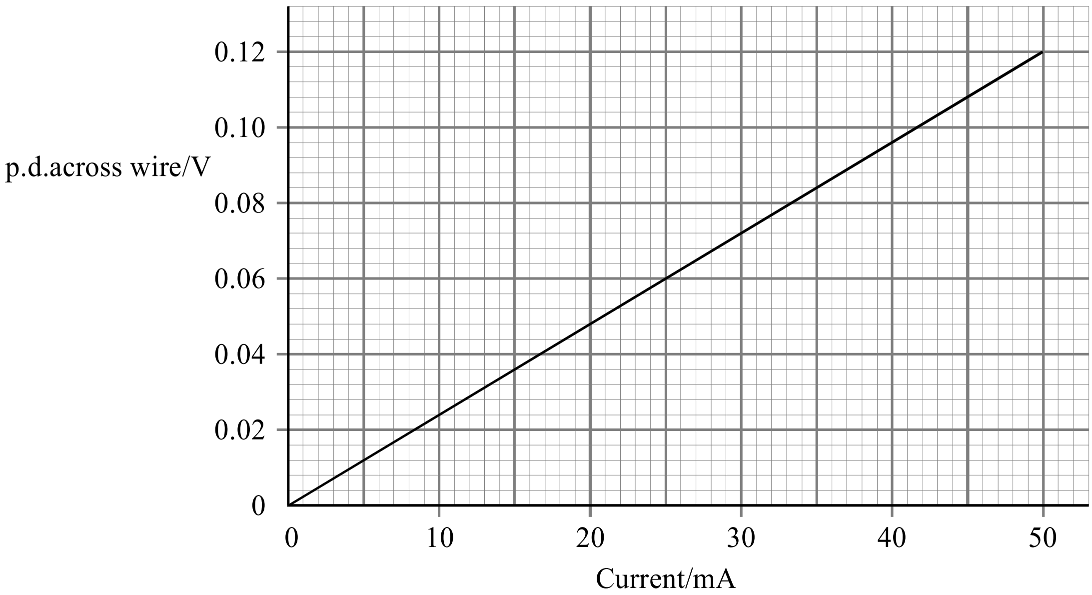
(2)

A number of measurements were made of the voltage across the wire for different values of the current flowing in it. The following graph was drawn.



Calculate the resistance of the nichrome wire.

....

....

....

Resistance =

(3)

The length of wire between the clamps is 51 cm. The diameter of the nichrome wire is 0.59mm.Calculate the resistivity of the nichrome.

....

....

....

Resistance =

(3)
(Total 12 marks)

39. A small house uses a tank containing 1.2 m ^{3} water as a thermal store. During the night its temperature rises to 98 ^{o}C. During the day, its temperature drops as the water is pumped round, the house radiators to keep the house warm.

The density of water is 1 000 kg m^{-3} and its specific heat capacity is 4200 J kg^{-1} K^{-1}. Calculate the energy given out by the water on a day when its temperature drops from 98 °C to 65 °C.

....

....

....

Energy = ...

(3)

The six radiators in the house give out an average power of 1.5 kW each. For how long can they all operate at this power before the water temperature drops to 65°C?

....

....

....

Time = ...

(3)

Explain why this heating system operates more effectively early in the morning than towards the evening.

....

....

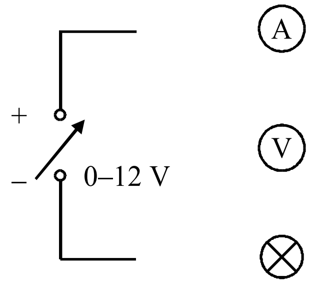
....

....

(2)
(Total 8 marks)

40. You are asked to set up a circuit to take some measurements and to draw a graph which shows how the current in a 12 V, 24 W electric filament lamp varies with the potential difference across it.

The diagram shows the electrical components you will need. Complete a suitable circuit diagram by drawing the connection wires.



(2)

What measurements would you make using this circuit?

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(3)

Sketch and label the graph you would expect to obtain.

(3)
(Total 8 marks)

41. A torch has three identical cells, each of e.m.f. 1.5 V, and a lamp which is labelled 3.5 V, 0.3 A. Draw a circuit diagram for the torch.

(2)

Assume that the lamp is lit to normal brightness and that the connections have negligible resistance. Mark on your diagram the voltage across each circuit component and the current flowing in the lamp.

(3)

Calculate the internal resistance of one of these cells.

Resistance = ...

(3)
(Total 8 marks)

42. Express the ohm and the farad in terms of SI *base* units.

Ohm ....

....

Farad ....

....

Hence show that ohm x farad = second.

....

....

....

....

(4)

Most d.c. power supplies include a smoothing capacitor to minimise the variation in the output voltage by storing charge. In a particular power supply, a capacitor of 40 000 μF is used. It charges up quickly to 12.0 V, then discharges to 10.5 V over the next 10.0 ms, and then charges again to 12.0 V. The process then repeats continually.

Calculate the charge on the capacitor at the beginning and at the end of the 10.0 ms discharge period.

Beginning ....

....

....

Charge ....

....

....

End ....

....

....

Charge ....

(3)

What is the average current during the discharge?

....

....

....

Average current = …………….…………

(3)

The discharge times for the smoothing capacitors in modern computer power supplies are reduced to a minimum. Explain one advantage of this reduced discharge time.

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....

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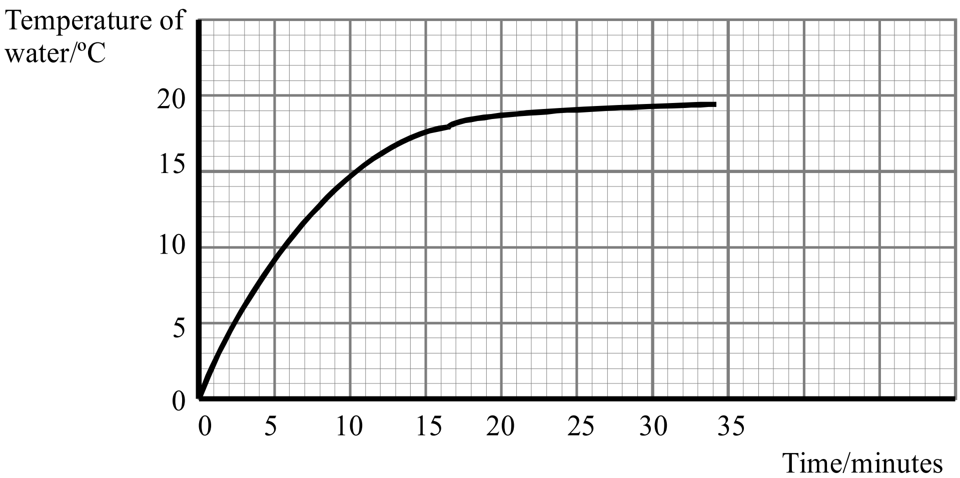
(2)
(Total 12 marks)

43. A thin beaker is filled with 400 g of water at 0°C and placed on a table in a warm room. A second identical beaker, filled with 400 g of an ice-water mixture, is placed on the same table at the same time. The contents of both beakers are stirred continuously.

The graph below shows how the temperature of the water in the *first* beaker increases with time.



Use the graph to find the initial rate of rise of water temperature. Give your answer in Ks^{-1}.

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………………………………………………………………………………………………

………………………………………………………………………………………………

Rate of rise = ……….......……..............

(2)

The specific heat capacity of water is 4200 J kg^{-1} K^{-1}. Use your value for the rate of rise of temperature to estimate the initial rate at which this beaker of water is taking in heat from the surroundings.

…………………………………………………………………………………………

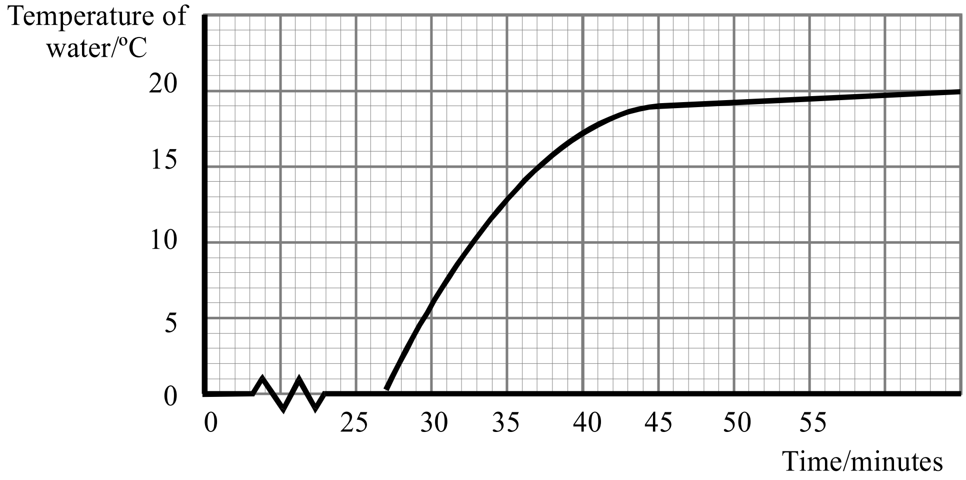
…………………………………………………………………………………………

…………………………………………………………………………………………

Rate of heat input = ……….........……...............

(3)

The graph below shows the temperature of the water in the second beaker from the moment it is placed on the table.



How do you explain the delay of twenty-seven minutes before the ice-water mixture starts to warm up?

…………………………………………………………………………………………

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(2)

The specific latent heat (enthalpy) of ice is 2.27 MJ kg^{-1}. Estimate the mass of ice initially present in the ice-water mixture.

…………………………………………………………………………………………

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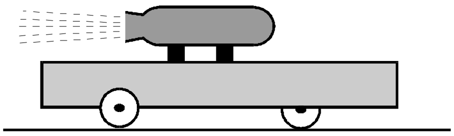
…………………………………………………………………………………………

Mass =……….........……...............

(4)
(Total 11 marks)

44. In a laboratory experiment a small cylinder containing liquid carbon dioxide is attached to a trolley. When the cylinder is punctured CO_2 gas rushes out and the trolley accelerates.



(a) Explain from first principles the origin of the force accelerating the trolley.

(3)

(b) The trolley and cylinder have a mass of 0.68kg and reach a final speed of 2.7 ms^{-1}.
The total mass of CO_2 initially in the cylinder is 12 g.

(i) Show that the average speed of ejection of CO_2 molecules during the acceleration is 150 ms^{-1}. State any assumption that you make.

(ii) Calculate the total kinetic energy of the CO_2 gas after it has left the cylinder and the kinetic energy of the trolley and cylinder at its final speed.

(7)

(c) It is found that the cylinder which contained liquid CO_2 is cold at the end of the experiment.

(i) Explain this drop in temperature.

(ii) What would you use to measure the change in temperature of the cylinder between the start and finish of the experiment? Give one possible source of error in your measurement.

(iii) What other measurement would you take and what data would you need to look up in order to calculate the loss in internal energy of the cylinder?

(6)
(Total 16 marks)

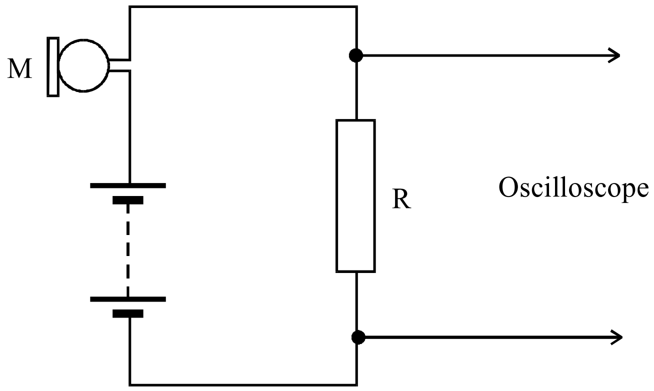
45. (a) Explain why sound waves cannot be plane polarised. How are sound waves in air usually generated?

The speed of sound in air c is related to the pressure p and density ρ of the air by the equation $c = (\gamma p/p)^{½}$ where γ is a dimensionless constant.

Show that the equation is homogeneous with respect to units.

(6)

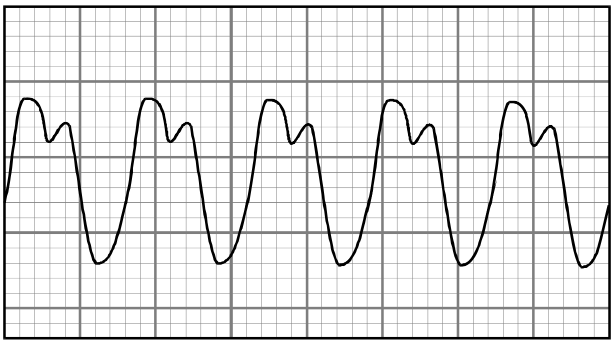
(b) In one type of microphone loosely packed carbon granules respond to changes of pressure produced by sound waves. When the granules are compressed the resistance of the microphone decreases. Such a microphone M is connected in a circuit as shown.



(i) Explain how the potential difference across the resistor R changes when the pressure at the microphone increases.

(2)

For a particular incident sound, the trace on the oscilloscope is as shown.



(ii) The settings on the oscilloscope are 0.20mV cm^{-1} and 250 μs cm^{-1}. Determine the frequency of the sound and the amplitude of the voltage change across the resistor R.

(5)

(iii) The trace shows that the sound is the result of the superposition of two waves. Describe an experiment which demonstrates the superposition of waves of wavelength about 30 mm, i.e. microwaves or water ripples.

(3)
(Total 16 marks)

46. State what is meant by "an equation is homogeneous with respect to its units".

....

....

(1)

Show that the equation $x = ut + 1/2at^2$ is homogeneous with respect to its units.

....

....

....

....

....

(3)

Explain why an equation may be homogeneous with respect to its units but still be incorrect.

....

....

(1)
(Total 5 marks)

47. (a) Describe how you would determine by experiment approximate values for the e.m.f and internal resistance of a torch battery. Include a circuit diagram.

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(4)

(b) (i) A battery has an e.m.f. of 12.0 V and an internal resistance of 3.0Ω.Calculate the p.d. across the battery when it is delivering a current of 3.0 A.

....

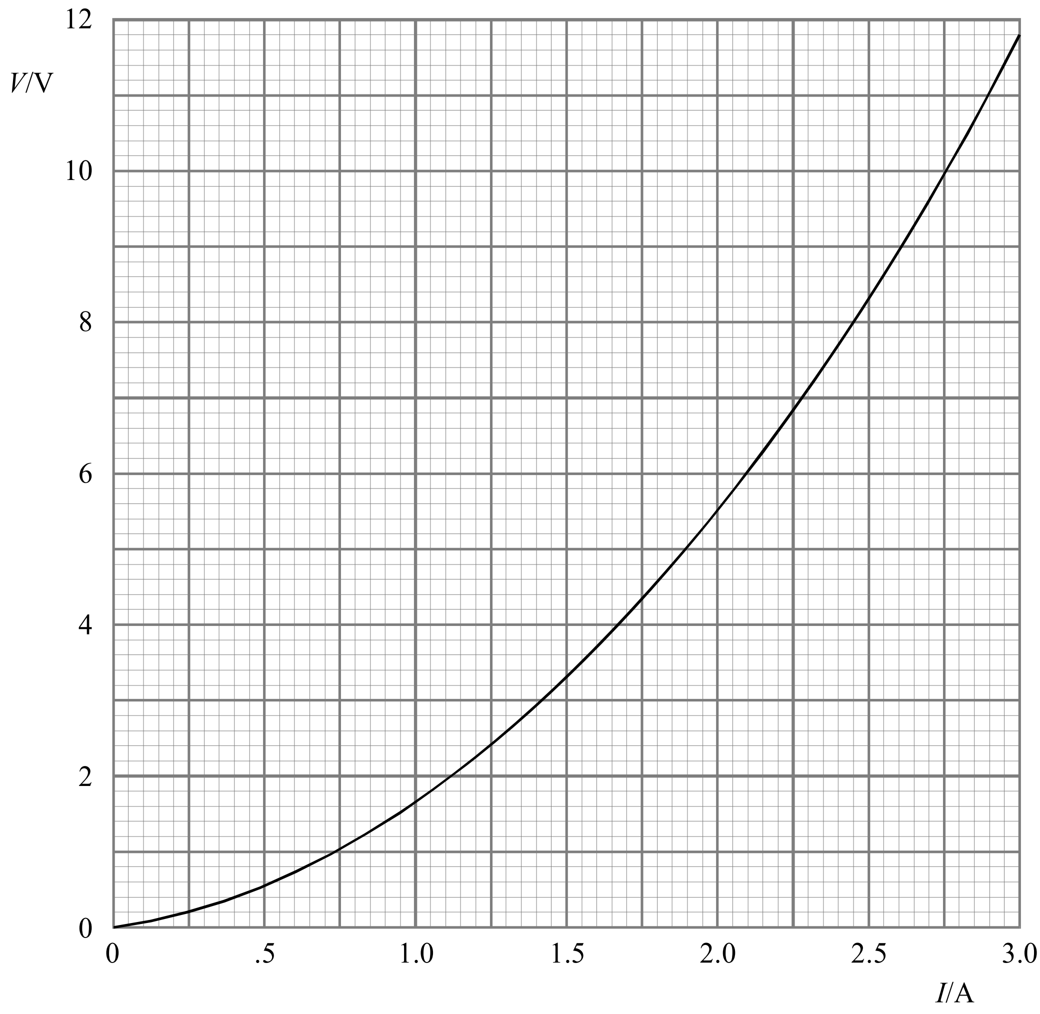
....

....

p.d. = ...

(2)

(ii) The same battery is now connected to a filament lamp. The graph shows how the p.d. across the lamp would depend on the current through it.



Use your answer to part (i) to help you draw, on the same axes, a line showing how the p.d. across the battery would depend on the current through it.

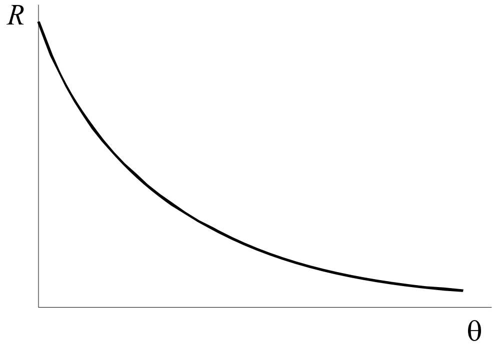
(1)

What current will the battery drive through the lamp?

....

(1)
(Total 8 marks)

48. The graph shows how the resistance R of a thermistor depends on temperature θ.



In terms of the behaviour of the material of the thermistor, explain qualitatively the variation shown on the graph.

....

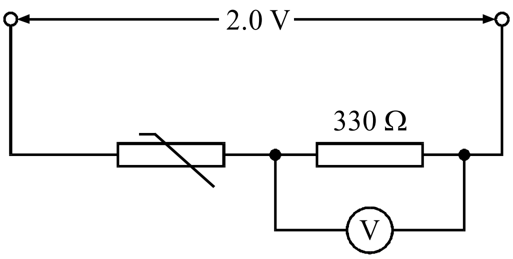
....

....

....

(2)

A student connects the thermistor in series with a 330 Ω resistor and applies a potential difference of 2.0 V. A high resistance voltmeter connected in parallel with the resistor reads 0.80 V.



Calculate the resistance of the thermistor.

....

....

....

Resistance = ...

(3)

The student now increases the applied p.d. from 2.0 V to 20 V. She expects the voltmeter reading to increase from 0.80 V to 8.0 V but is surprised to find that it is greater. Explain this.

....

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....

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....

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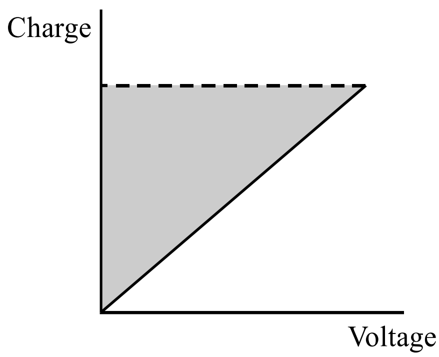
(3)
(Total 8 marks)

49. The diagram shows a graph of charge against voltage for a capacitor.



What quantity is represented by the slope of the graph?

....

What quantity is represented by the shaded area?

....

(2)

An electronic camera flash gun contains a capacitor of 100 μF which is charged to a voltage of 250 V. Show that the energy stored is 3.1 J.

....

....

....

....

....

(2)

The capacitor is charged by an electronic circuit that is powered by a 1.5 V cell. The current drawn from the cell is 0.20 A. Calculate the power from the cell and from this the minimum time for the cell to recharge the capacitor.

....

....

....

....

Minimum time = ...

(3)
(Total 7 marks)

50. Transfers of energy may be either *heating* or *working*.

When an electric fire is used to warm a room the energy is transferred in several stages. For each of the stages listed below say whether the energy transfer is heating or working, and give a reason for your answer.

(a) From the power supply to the element.

....

....

....

....

(b) From the element to the surrounding air.

....

....

....

....

(Total 4 marks)

51. (a) (i) Radioactivity is a random process. Explain what is meant by this statement.

(ii) The decay of a sample of radioactive material can be described by the equation.

$$\frac{dN}{dt} = -\lambda N$$

where d*N*/dt is the activity of the sample.

Calculate the activity of a sample of nitrogen–13 when N=2.5 × 10^5. The half-life of nitrogen–13 is 10 minutes.

(iii) Nitrogen–13 ($^{13}_{7}N$) decays to a stable nuclide by emitting a beta-plus particle. Write an equation for this process.

(7)

(b) A student develops an experiment, shown in figure (i), to model a radioactive decay process such as that for nitrogen–13. A burette containing copper sulphate solution is allowed to drain into a beaker. The student monitors the levels of the copper sulphate solution in the burette and beaker.

(i) Discuss to what extent the experiment illustrated in figure (i) is analogous to the decay of nitrogen–13.

(3)

Figure (i)

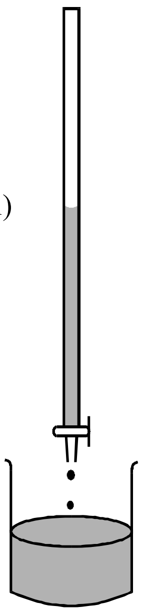
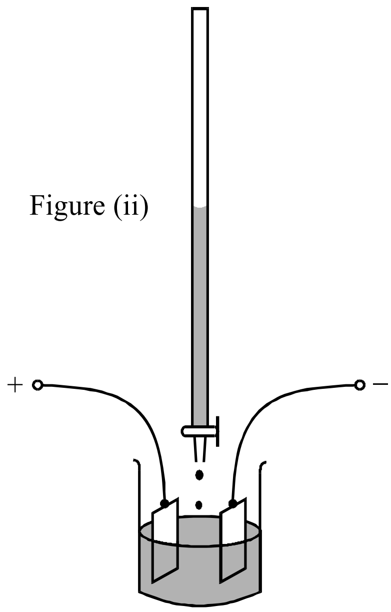


Figure (ii)



(ii) The student develops an electrical method of monitoring the depth of solution in the beaker. This is shown in figure (ii). Two square sheets of copper of side 4.0cm are placed 5.0cm apart in the beaker. The copper sheets are connected in series with a d.c. supply of 1.5V, an ammeter and a 5.6Ω resistor.

Calculate the current in the circuit when the copper sulphate solution covers half the copper sheets. Take the resistivity of copper sulphate solution to be 0.12Ωm. State any assumption you have made.

(6)
(Total 16 marks)

52. The joule is the SI unit of energy. Express the joule in the base units of the SI system.

....

....

(1)

A candidate in a physics examination has worked out a formula for the kinetic energy E of a solid sphere spinning about its axis. His formula is

$$E = \tfrac{1}{2}\rho r^5 f^2,$$

where ρ is the density of the sphere, r is its radius and f is the rotation frequency. Show that this formula is homogeneous with respect to base units.

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(3)

Why might the formula still be incorrect?

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(1)
(Total 5 marks)

53. The current I through a metal wire of cross-sectional area A is given by the formula

$$I = nA\upsilon e$$

where e is the electronic charge on the electron. Define the symbols n and υ.

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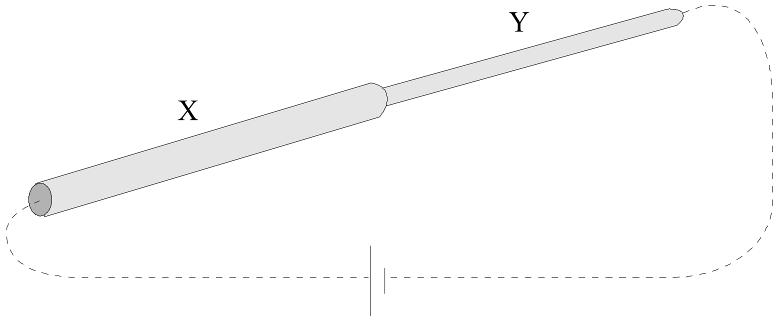
(2)

Two pieces of copper wire, X and Y, are joined end-to-end and connected to a battery by wires which are shown as dotted lines in the diagram. The cross-sectional area of X is double that of Y.



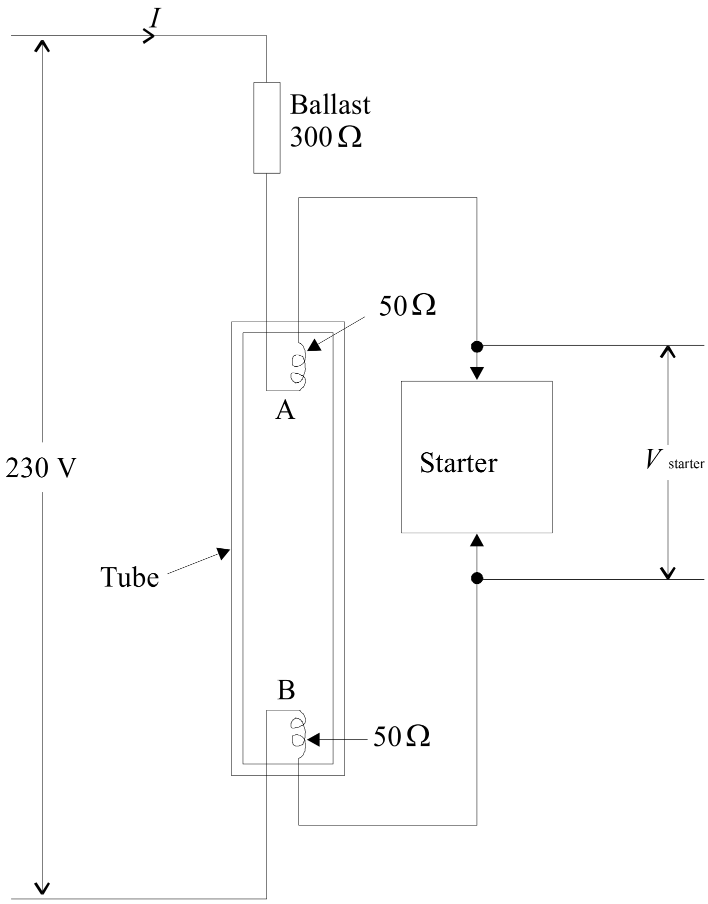
In the table below, n_x and n_y denote the values of n in X and Y, and similarly for the other quantities. Write in the table the value of each ratio, and alongside it explain your answer.

Ratio	Value	Explanation
$\frac{n_Y}{n_X}$		
$\frac{I_Y}{I_X}$		
$\frac{\upsilon_Y}{\upsilon_X}$		

(6)
(Total 8 marks)

54. The diagram shows the circuit of a fluorescent light fitting. It consists of a tube, a starter and a ballast resistance of 300 Ω.

The fluorescent tube is filled with gas. It contains two filaments at A and B of resistance 50 Ω that heat the gas.



When the light is first turned on, the tube does not conduct but the starter does, drawing a current of 0.50 A from the 230 V supply.

Calculate the voltages across the ballast resistor and each filament when this current flows.

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....

Voltage across ballast = ...

Voltage across each filament = ...

(3)

Mark these voltages on the diagram, and hence calculate the voltage across the starter when the starting current is flowing. Mark your answer on the diagram.

(2)

The starting current heats the filaments and the gas in the tube but the voltage across the tube is not large enough to make it conduct. However, after a few seconds the starter stops conducting. The voltage across the tube rises and the gas conducts. A current now flows from A to B and the tube lights up.

What fundamental change is necessary for a gas, which was an insulator, to be able to conduct?

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....

(1)

Now that the tube is conducting, the voltage across AB is 110 V. Calculate the power dissipated in the whole circuit.

....

....

....

Power dissipated =................................

(3)

In a faulty fluorescent lamp the filaments at both ends of the tube glow steadily but the tube does not light up. Identify, with a reason, the faulty component.

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(1)
(Total 10 marks)

55. An electric shower is connected to the mains supply by a copper cable 20 m long. The two conductors inside the cable each have a cross-sectional area of 4.0 mm^2 **.** The resistivity of copper is 1.7×10^{-8} Ω . Show that the resistance of each of the conductors is 0.085 Ω.

....

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(2)

The operating current of the shower is 37 A. Calculate the total voltage drop caused by the cable supplying the shower.

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....

....

Voltage =...

(2)

Explain why cable with 6.0 mm^2 conductors would have been more suitable for this shower installation.

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....

(2)
(Total 6 marks)

56. Draw a diagram of the apparatus you would use to demonstrate Brownian motion in a gas.

(3)

Describe what you would see and explain how this gives evidence for the molecular constitution of a gas.

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....

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(3)
(Total 6 marks)

57. A student connects a power supply to a block of lead. The block is thermally insulated from its surroundings. A voltage of 0.42 V drives a current of 23 A through the block. The temperature of the block rises 1.5 K above the room temperature in 30 s. Show that the energy given to the block is about 300 J.

....

....

....

....

....

(2)

The equation $\Delta U = \Delta Q + \Delta W$ applies to the block during this process. For each of these three terms state, with a reason, its value.

ΔU ....

....

ΔQ ....

....

ΔW ....

....

(6)

In a second experiment the student beats one side of the block a number of times with a hammer. He hits the same spot each time. During this process the block is indented by a distance of 2.4 mm and its temperature rises by 1.5 K. Calculate the average force applied by the hammer.

....

....

....

Force =...

(3)

(Total 11 marks)

58. A quantity of air is contained in a gas-tight syringe. The piston is clamped so that the volume of the air is fixed at 50 cm^3. When the air is at 0 °C its pressure is 1.00×10^5 Pa. The apparatus is now heated to 100 °C.

Calculate the pressure of the air at 100 °C.

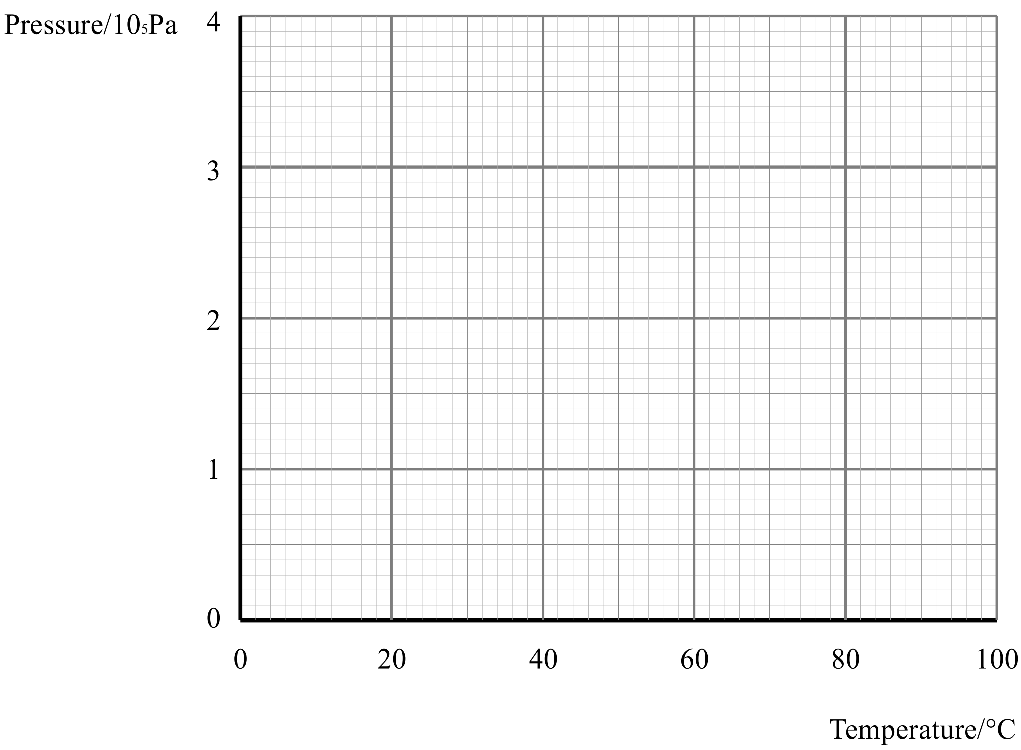
....

....

Pressure =..................................

(2)

On the axes below draw a graph to show how the air pressure varies with temperature over the range 0 °C to 100 °C. Label your graph A.

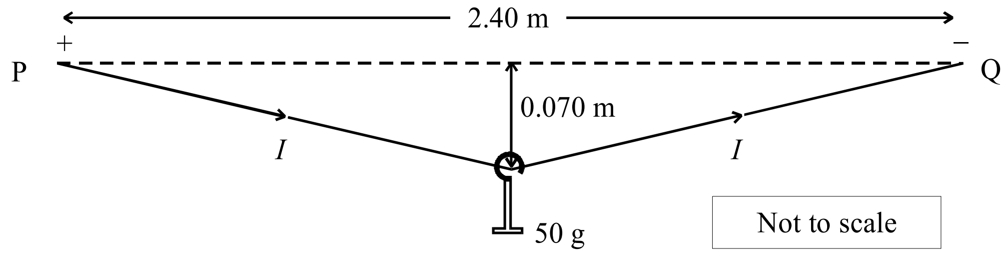


(2)

The piston is pushed in until the air volume is 25 cm^3. The piston is then clamped. On the same axes draw a second graph, labelled B, to show how the pressure would now vary over the same temperature range.

(2)
(Total 6 marks)

59. A student devises a way of measuring electric current by hanging a mass of 50 g on a conducting wire stretched between two points P and Q which are 2.40 m apart. The sag at the centre of the wire varies with the current *I*, as the wire expands because of the heating effect of the current. The sag is 0.070 m when the current is 13 A d.c.



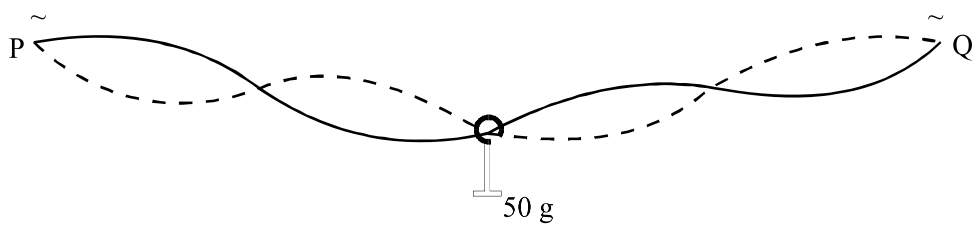
(a) Draw a free-body force diagram for the 50 g mass when the sag is 0.070 m. Hence, or otherwise, determine the tension *T* in the wire.

(5)

(b) Outline how the student could have measured the resistance of the conducting wire at different values of *I* before setting up this experiment.

(3)

(c) The student now connects P and Q to a 50 Hz a.c. supply. When the current is 13 A r.m.s. the wire is found to oscillate as shown.



The student measures the distance between adjacent nodes along the wire to be 606 mm.

(i) What is meant by a current of 13 A r.m.s.?

(ii) Deduce the speed *c* of transverse waves along the hot wire.

(iii) Suggest why the wire oscillates in this manner.

(6)

(d) The tension in the wire is related to c and the mass per unit length μ of the wire by the expression

$$T = \mu c^2$$

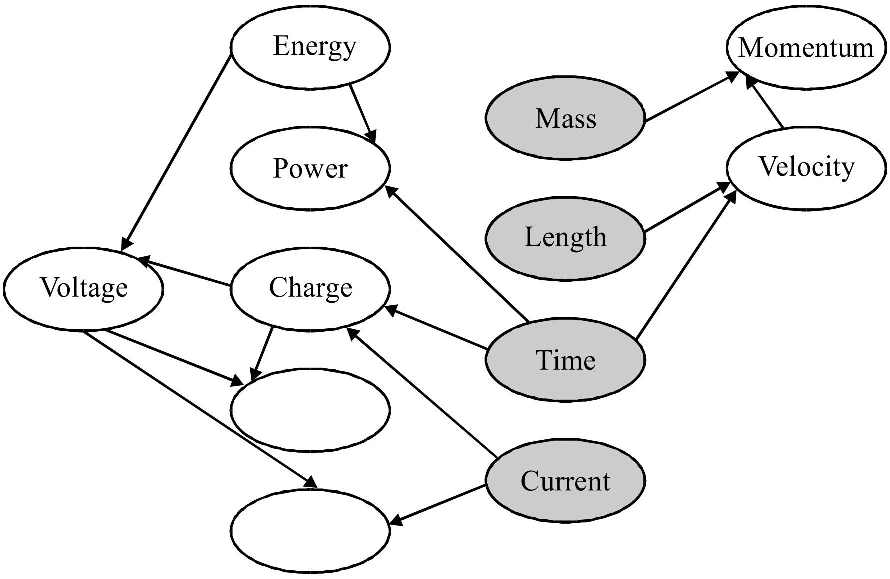
Show that the unit of μc^2 is N.

(2)
(Total 16 marks)

60. Many physical quantities are defined from two other physical quantities.

The diagram shows how a number of different quantities are defined by either multiplying or dividing two other quantities.

Write correct quantities in the two blank ellipses below.



(2)

Explain what is special about the physical quantities in the shaded ellipses.

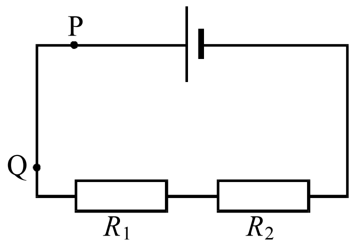
....

....

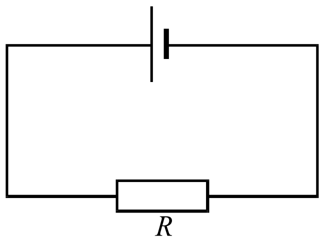
....

(2)
(Total 4 marks)

61. The resistors R_1 and R_2 in circuit (i) are equivalent to a single resistor R in circuit (ii).



(i)



(ii)

Prove that $R = R_1 + R_2$

....

....

....

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....

....

(3)

In a real circuit it is usually assumed that there is no potential difference between two points, such as P and Q in diagram (i), which are on the same connecting lead. Explain why this is usually a good approximation.

....

....

....

(2)

In what circumstances might the approximation break down?

....

....

(1)

A laboratory lead consists of 16 strands of fine copper wire twisted together. Each strand is 30 cm long with a diameter of 0.15 mm. Calculate the potential difference across the lead when it is carrying a current of 2.0 A.

(The resistivity of copper = 1.7×10^{-8} Ωm**)**

....

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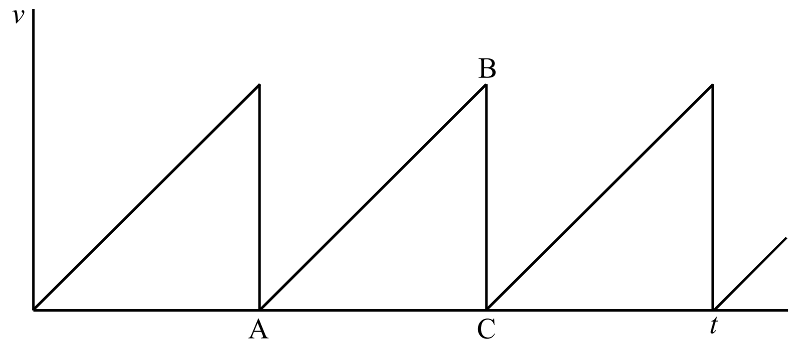
Potential difference =..................................

(4)

(Total 10 marks)

62. The diagram is a velocity-time graph for an electron.



Describe carefully the motion represented by lines AB and BC.

AB: ....

....

BC: ....

....

(2)

The graph is a much simplified model of how an electron moves along a wire carrying a current. Explain what causes the motion represented by AB and BC.

AB: ....

....

BC: ....

....

(2)

Explain the term *drift velocity* and indicate its value on the graph above.

....

....

(2)

With reference to the behaviour of the electron, explain why the wire gets warm.

....

....

(1)
(Total 7 marks)

63. An electric kettle has a power of 2.4 kW. It contains boiling water at 100 °C. Calculate how long it takes to boil away 0.50 kg of water. (The specific latent heat of vaporisation of water is 2.2 MJ kg^{-1}.)

....

....

....

Time taken =.................................

(2)

0.50 kg of water contains 27.8 mol of water and occupies a volume of $0.00050 m^3$.

Show that the volume of the water vapour it produces at 100 °C is approximately 0.9 m^3. (Atmospheric pressure is 1.01×10^5 Pa.)

....

....

....

....

(3)

Calculate the work done by the water pushing the atmosphere back as it turns from liquid into vapour.

....

....

....

....

Work done =..................................

(3)

The equation $\Delta U = \Delta Q + \Delta W$ is applied to the 0.50 kg of water during the process of converting it to vapour. What are the values of each of the three terms?

ΔQ ....

ΔW ....

ΔU ....

(3)
(Total 11 marks)

64. On the axes below, sketch a graph to show how the pressure of a fixed mass of air at room temperature depends on its volume.

(2)

In terms of the behaviour of molecules, explain qualitatively the shape of your graph.

....

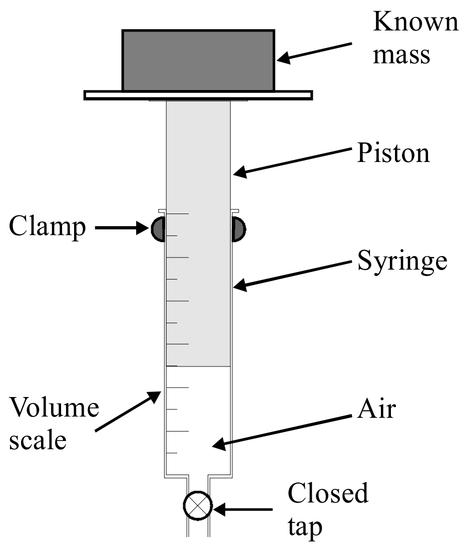
....

....

....

(2)

The diagram shows apparatus which could be used to check the shape of your graph.



How would you calculate the pressure of the air in the syringe?

....

....

....

....

(2)

Suggest one possible source of error in this experiment, other than errors in scale readings.

....

....

(1)
(Total 7 marks)

65. A tennis ball, moving horizontally at a high speed, strikes a vertical wall and rebounds from it.

(a) Describe the energy transfers which occur during the impact of the ball with the wall.

(2)

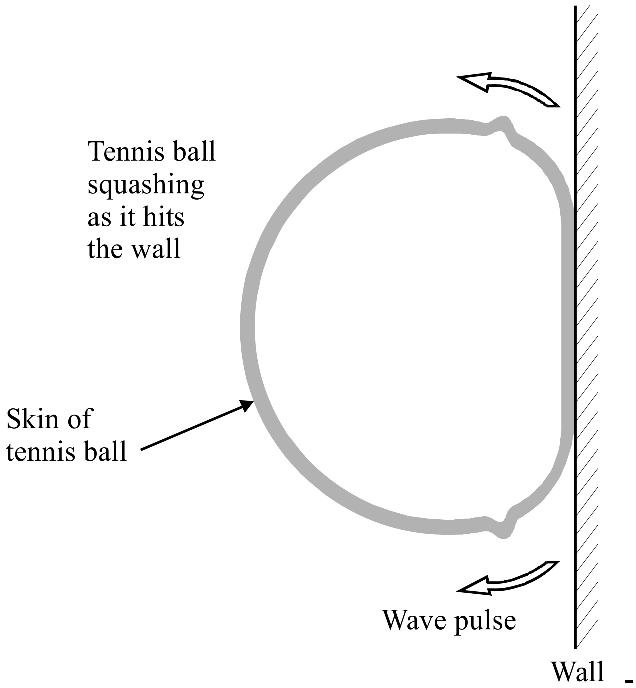
(b) During the impact the volume of gas in the tennis ball decreases from V to 0.84V. The initial pressure of the gas in the ball is 116 kPa.

(i) Show that the increase in pressure which this produces is 22 kPa assuming that the temperature of the gas remains constant.

(ii) In practice the gas pressure increases by 32 kPa, since the temperature changes as the ball is squashed. Explain this increase in pressure in molecular terms.

(6)

(c) As a result of the impact, a ring-like wave pulse travels along the "skin" of the tennis ball.



The speed c of this pulse in the skin of the ball is given by

$$c = \left(\frac{2\pi a^3 \Delta p}{m}\right)^{\frac{1}{2}}$$

where m is the mass of the tennis ball, a its radius and Δp is the difference between the pressure of the gas inside the ball and atmospheric pressure.

(i) The time of contact t_c of the ball with the wall is the time taken for this wave pulse to move to the non-impact side of the ball, i.e. half way round its circumference.

For a ball of mass 57.5 g and radius 33.5 mm, estimate t_c. Take atmospheric pressure to be 100 kPa and refer to the pressure data in *(b)*.

(5)

(ii) Suggest a method by which you could measure the time of contact of the tennis ball and the wall to a precision of about a millisecond.

(3)
(Total 16 marks)

66. (a) The shaded square in the diagrams represents a piece of resistance paper. The surface of the paper is coated with a conducting material. In the figure below two metal electrodes E_1 and E_2 are placed on the resistance paper and connected to a battery.

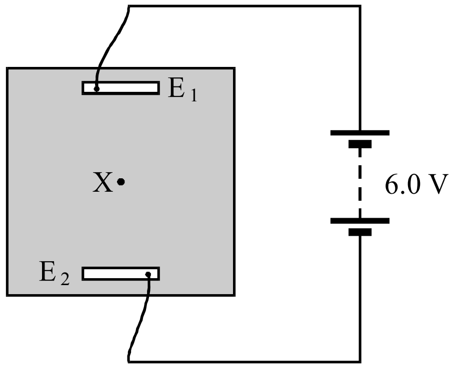


Figure 1

(i) Sketch the electric field in the region between E_1 and E_2.

(ii) E_1 and E_2 are 15 cm apart. What is the strength of the electric field at X, a point half-way between them?

(iii) Add and label three equipotential lines in the region between E_1 and E_2.

(7)

(b) Figure 2 shows two 470 Ω resistors and a milliammeter connected to the initial arrangement. The other side of the milliammeter is connected to a metal probe which makes contact with the surface of the resistance paper.

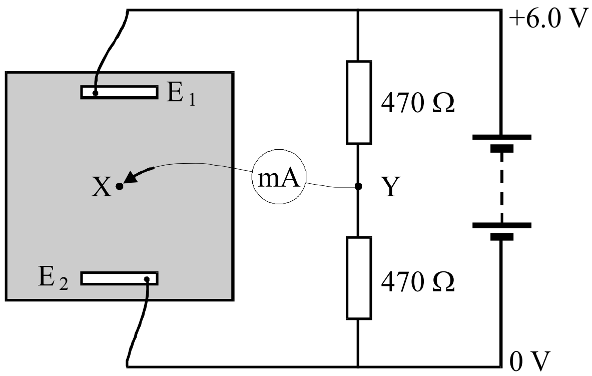


Figure 2

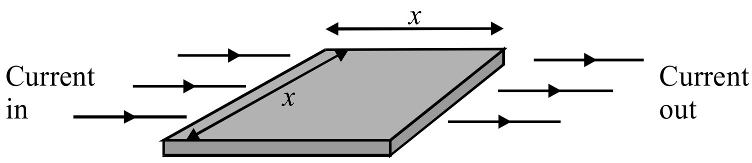
(i) The metal probe is moved over the resistance paper surface. When the probe is at X the milliammeter registers zero. State the potential at X and explain why the milliammeter registers zero.

(ii) Describe how you would adapt the apparatus to find the potentials at other points on the resistance paper.

(5)

(c) The resistance of a square piece - a tile - of the resistance paper is given by $R = \rho/t$, where ρ is the resistivity and t the thickness of the material forming the conducting layer.

(i) By considering a square of side x as shown, prove that $R = \rho/t$, i.e. that the resistance of the tile is independent of the size of the square.



(ii) Calculate the resistivity of a material of thickness 0. 14 mm which has a resistance of 1000 ohms for a square of any size.

(4)
(Total 16 marks)

67. The current I flowing through a conductor of cross-sectional area A is given by the formula

$$I = nAQv$$

where Q is the charge on a charge carrier. Give the meanings of n and v.

n ....

v ....

(2)

Show that the equation is homogeneous with respect to units.

....

....

....

....

(3)

With reference to the equation, explain the difference between a metal conductor and a plastic insulator.

....

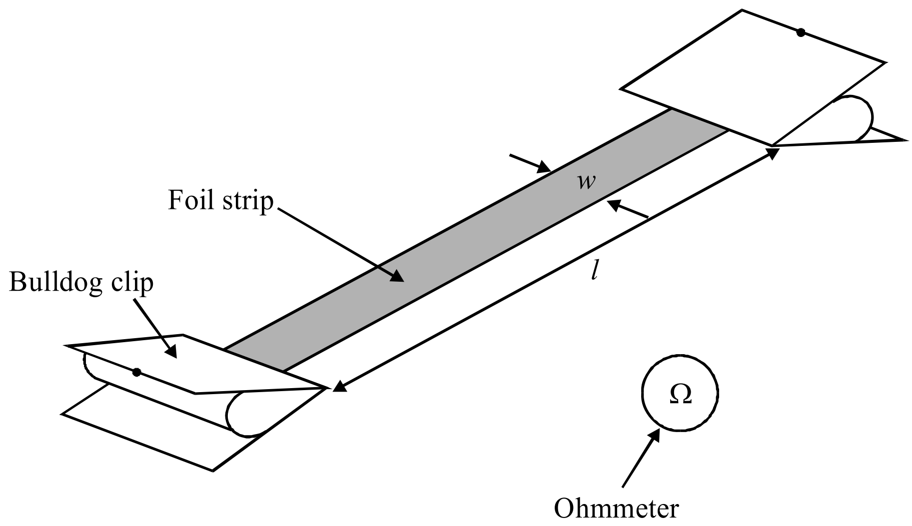
....

....

....

(2)
(Total 7 marks)

68. A student is planning an experiment to measure the resistivity of aluminium. She plans to use an ohmmeter to measure the resistance of a rectangular strip of aluminium foil fastened between two bulldog clips.



She also intends to measure the thickness t of the foil and the length 1 and width w of the strip.

Explain how she should calculate the resistivity from her measurements.

....

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....

....

(2)

The student decides that for sufficient accuracy the resistance of the strip must be at least 1.0 Ω. To see what dimensions would be suitable, she does some preliminary experiments using strips 20 mm wide cut from foil 0.15 mm thick. She finds that for strips of a convenient length the resistance is far too small.

Calculate the length of strip, 20 mm wide and 0.15 mm thick, which would have a resistance of 1.0 Ω (Resistivity of aluminium = 2.7×10^{-8} Ω m)

....

....

....

Length =..

(3)

Suggest a way, other than increasing its length, by which she could increase the resistance of her strip. Comment on whether this change would lead to a more precise measurement of the resistivity.

....

....

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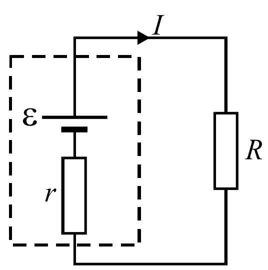
....

(2)
(Total 7 marks)

69. The diagram below shows a cell, of e.m.f. ε and internal resistance r, driving a current I through an external resistance R.



Using these symbols, write down a formula for

(i) the power dissipated in the external resistance

....

(ii) the power dissipated in the internal resistance

....

(iii) the rate of conversion of chemical energy in the cell

....

Using these formulae, write down an equation expressing conservation of energy in the circuit, and hence show that $I = \dfrac{\varepsilon}{(R + r)}$

....

....

....

(5)

The equation $I = \varepsilon / (R + r)$ shows that the internal resistance of a power supply limits the current which can be drawn from it. Explain this.

....

....

....

....

(2)

A 5 kV laboratory supply can be made safe for student use by connecting an internal series resistor. The following resistors are available:

1 kΩ   10 kΩ   100 kΩ   1 MΩ

Explain which resistor should be used to make the supply as safe as possible.

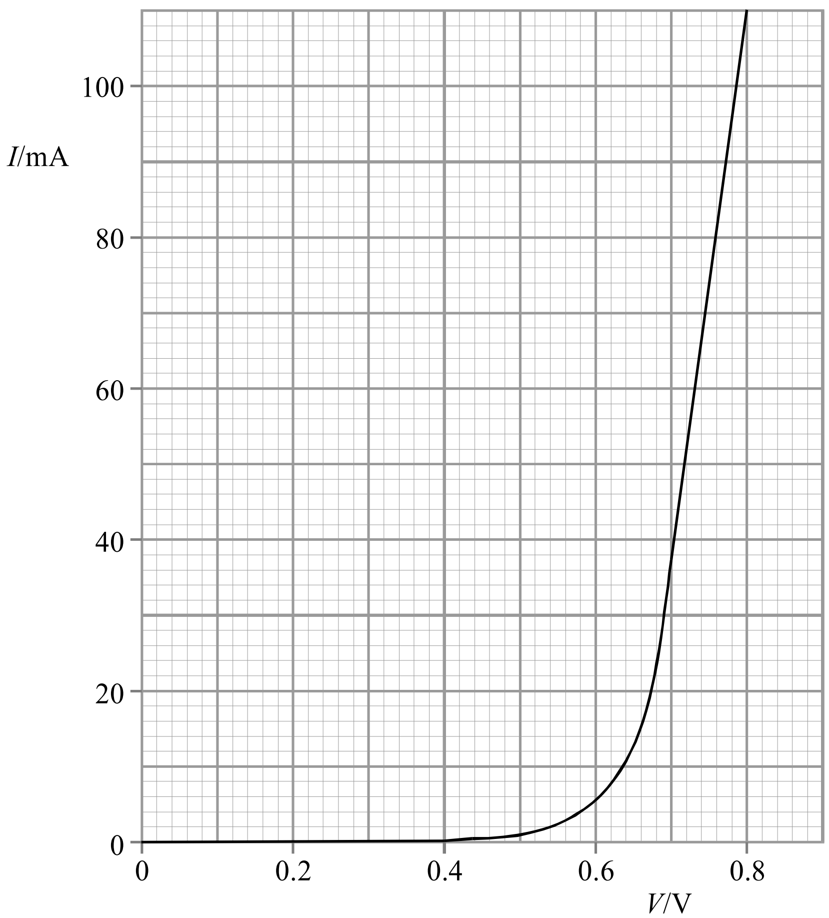
....

....

....

(2)
(Total 9 marks)

70. The graph shows the current-voltage characteristic of a semiconductor diode.



State, with a reason, whether the diode obeys Ohm's law.

....

....

(1)

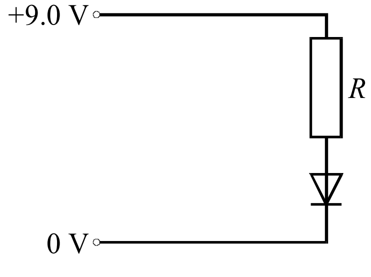
Show that when the voltage across the diode is 0.74 V its resistance is about 9 Ω.

....

....

(2)

When the diode is connected in the following circuit, the voltage across it is 0.74 V.



Calculate the value of the resistance *R*.

....

....

....

R = ...
(3)

Electronic circuit designers often use a simple model of this type of diode. This “model diode” has the following properties:

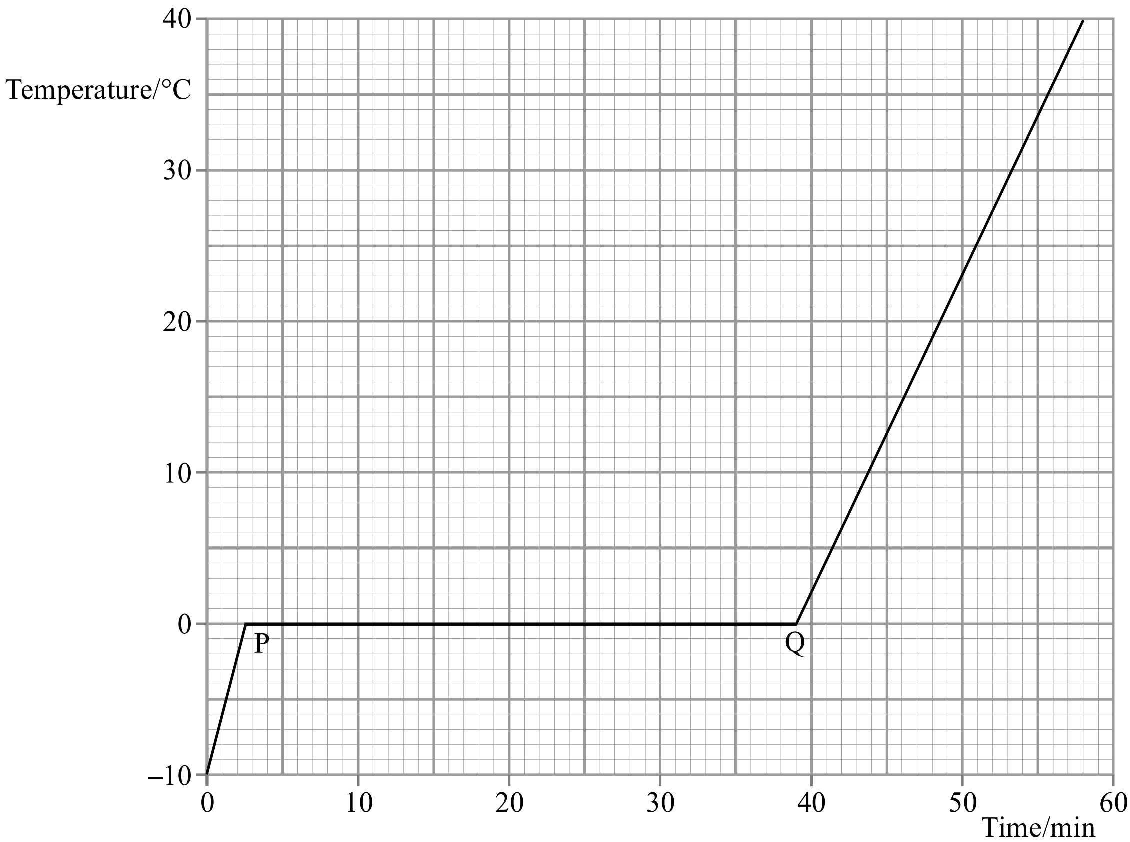
(i) For any voltage below +0.7 V it does not conduct at all.

(ii) Once the voltage reaches +0.7 V the diode can pass any size of current with no further increase in voltage.

Add a second graph to the grid above to show the current-voltage characteristic of this model diode.

(2)
(Total 8 marks)

71. A well-insulated vessel contains 0.20 kg of ice at –10 °C. The graph shows how the temperature of the ice would change with time if it were heated at a steady rate of 30 W and the contents were in thermal equilibrium at every stage.



Describe in terms of molecules the change which occurs between points P and Q.

....

....

....

....

(2)

Use the graph to determine the specific latent heat of fusion of water.

....

....

....

Specific latent heat of fusion ....

(3)

A student tries to plot this graph experimentally. He places crushed ice at –10 °C in a well-insulated beaker containing a small electric heater. What additional equipment would he need, and how should he use it, to obtain the data for his graph?

....

....

....

....

(2)

Suggest one precaution he should take to try to get an accurate graph.

....

....

(1)

Gallium is a metal with a melting point of 29 °C. Its specific heat capacity, in both the solid and liquid state, and its specific latent heat of fusion, are all smaller than those of water. Add to the graph above a second line showing the results you would expect if 0.20 kg of gallium, initially at –10 °C, was heated at the same rate of 30 W.

(3)
(Total 11 marks)

72. According to kinetic theory, the pressure p of an ideal gas is given by the equation

$$p = \tfrac{1}{3}\rho\langle c^2\rangle$$

where ρ is the gas density and $\langle c^2\rangle$ is the mean squared speed of the molecules.

Express ρ in terms of the number of molecules N, each of mass m, in a volume V.

....

....

(1)

It is assumed in kinetic theory that the mean kinetic energy of a molecule is proportional to kelvin temperature T. Use this assumption, and the equation above, to show that under certain conditions p is proportional to T.

....

....

....

....

(2)

State the conditions under which p is proportional to T.

....

....

....

(2)

A bottle of gas has a pressure of 303 kPa above atmospheric pressure at a temperature of 0°C. The bottle is left outside on a very sunny day and the temperature rises to 35°C.
Given that atmospheric pressure is 101 kPa, calculate the new pressure of the gas inside the bottle.

....

....

....

....

Pressure = ...

(3)
(Total 8 marks)

73. A 60 W tungsten filament bulb is operating at its normal working temperature of 1600 °C. The equation $\Delta U = \Delta Q + \Delta W$ may be applied to the lamp filament. State and explain the **value** of each quantity for a period of 10 seconds' operation.

ΔU = ...

Reason ....

....

ΔW = ...

Reason ....

....

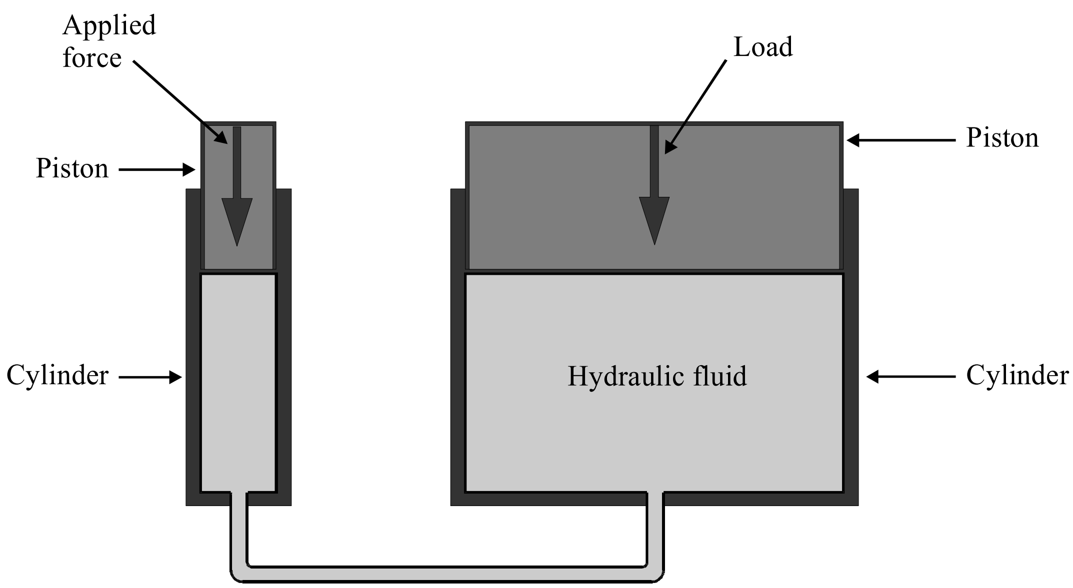
ΔQ = ...

Reason ....

....

(Total 6 marks)

74. The diagram shows a simplified hydraulic jack.



With reference to the diagram, explain the principle of how a hydraulic jack may be used to raise the chassis of a car. You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

....

(Total 4 marks)

75. A physics textbook states that the electron beam in a TV set transfers a charge Q to the screen in a time t such that

$$Q = net$$

What do n and e represent in this equation?

....

....

....

(3)

A student attempting to prove the equation shows that $Q = \frac{1}{2} net$.

Why will testing the homogeneity of this relationship *not* reveal that the student has made a mistake in his proof?

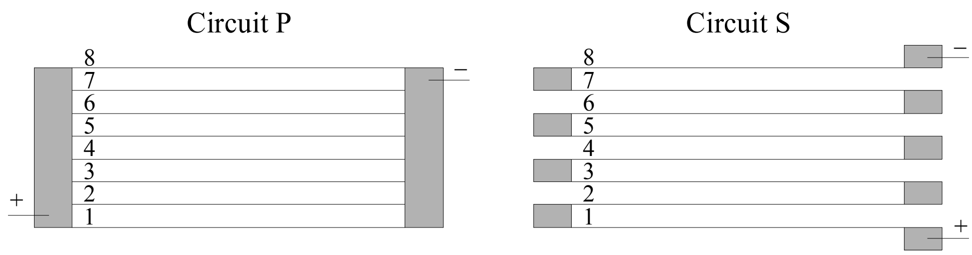
....

....

(1)

(Total 4 marks)

76. The diagram shows two methods of connecting eight heating elements which make up a car rear window heater. The heater is connected to a 12 V car battery. Each element used in circuit P has a resistance of 24 Ω;each used in circuit S has a resistance of 0.50 Ω.



(a) Calculate the current drawn from the battery for each circuit. Show your working.

Circuit P ....

....

....

Circuit S ....

....

....

(5)

(b) Elements 3 and 4 burn out in each circuit and no longer conduct electricity. What are the new values of the currents in each circuit?

Circuit P ....

....

Circuit S ....

....

(2)

(c) What effect would halving the battery voltage have on the power transfer in circuit P? Explain your answer.

....

....

....

....

(2)
(Total 9 marks)

77. A light-dependent resistor may be used with additional components to make a light meter. Sketch a diagram of a suitable circuit.

(2)

Explain how your circuit works.

....

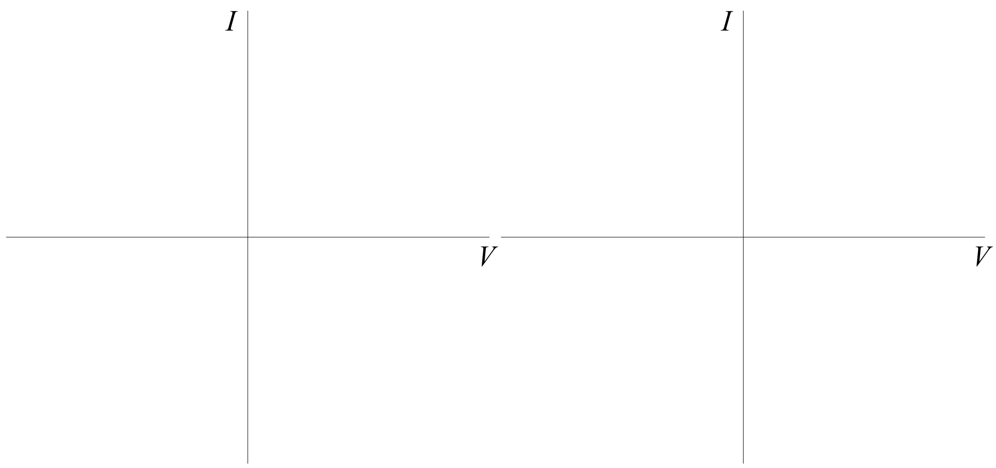
....

....

....

(2)
(Total 4 marks)

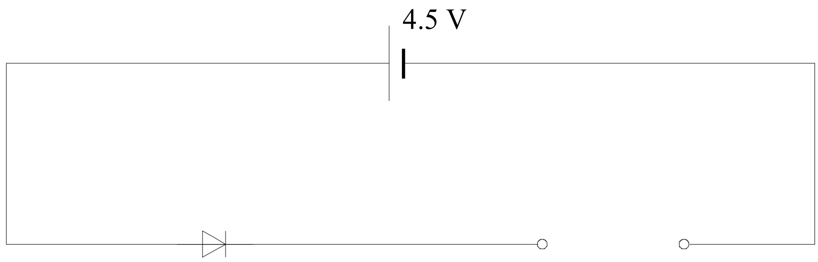
78. Use the axes below to sketch and label two graphs to show how the current varies with potential difference for (i) a metal wire, and (ii) a semiconductor diode, both at constant temperature.



Metal wire   Semiconductor diode

(3)

A semiconductor diode carries a current of 20 mA in normal operation. The potential difference across it should be 1.9 V. Complete the diagram below to show how, with the addition of a single component, the semiconducting diode may be powered from a 4.5 V supply.



Show that the resistance of the additional component is 130 Ω.

....

....

....

(3)
(Total 6 marks)

79. A pencil "lead "is made from non-metallic material which has a resistivity, at room temperature, of 4.0×10^{-3} Ω m.

A piece of this material has a length of 0.15 m (15 cm) and a diameter of 1.40×10^{-3} m (1.4 mm).

Show that the resistance of this specimen, to two significant figures, is 390 Ω.

....

....

....

....

(2)

The material from which pencil lead is made has a negative temperature coefficient of resistance. Explain what this means.

....

....

(2)

During an experiment to measure its resistance, a specimen of pencil lead is found to have a resistance of 420 Ω when the current in it is 250 mA.

Calculate the power dissipated in the specimen under these conditions.

....

....

....

(2)

When left for a few minutes after a potential difference is applied, it is observed that the current through the specimen increases substantially although the applied potential difference remains constant. Explain why the current should increase in this way. You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

(3)
(Total 9 marks)

80. You are asked to measure the specific heat capacity of aluminium using a cylindrical block of aluminium which has been drilled out to accept an electrical heater and a thermometer.

Draw a complete diagram of the apparatus you would use.

(3)

List the measurements you would take and explain how you would calculate the specific heat capacity of aluminium from your measurements.

....

....

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....

....

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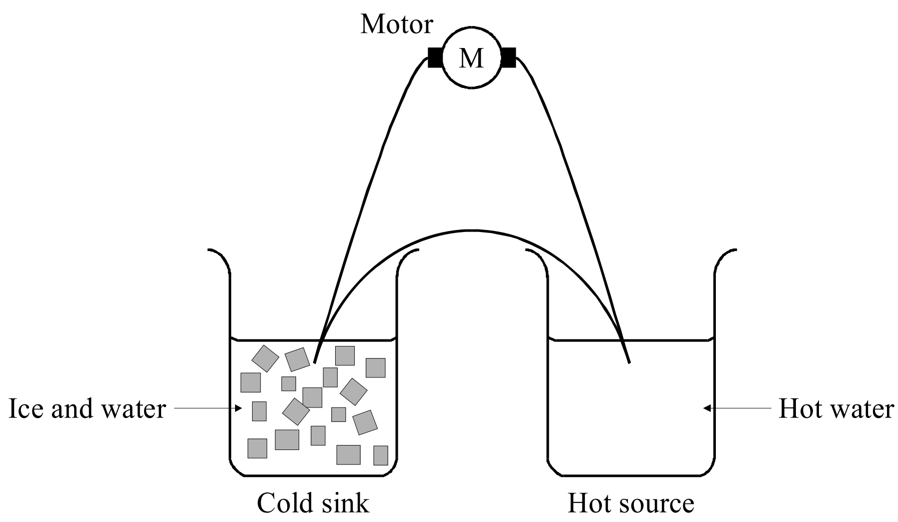
....

(6)
(Total 9 marks)

81. A simple heat engine which drives an electric motor is shown below. The wires connecting the motor to the hot source and the cold sink are made of the same material.
The wire linking the source and the sink is made of a different material.



State where the energy comes from and to where it goes.

....

....

....

....

(2)

Explain which energy transfers are heating and which are working. You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

....

....

(5)

Explain one way of increasing the efficiency of this heat engine.

....

....

....

....

(2)
(Total 9 marks)

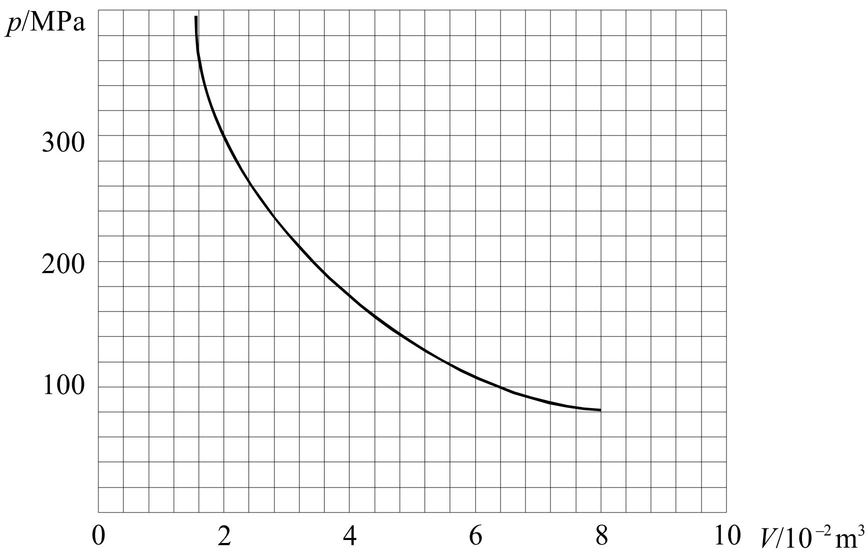
82. The relationship pV = constant applies to a sample of a gas provided that two other variables are constant. Name the two other variables.

....

....

(2)

The graph below shows the variation of pressure p with volume V for an ideal gas at a temperature of 300 K.



Add a second line to the graph showing the relationship between pressure and volume for the same sample of gas at a temperature of 400 K.

(2)
(Total 4 marks)

83. An air bubble released from a diver's breathing apparatus at a depth of 40 m has a diameter of 2.0 cm. When it reaches the surface of the water it has a diameter of 3.4 cm.

Show that the volume of the air bubble has increased by a factor of approximately 5.

....

....

....

(1)

Hence calculate the increase in pressure experienced by the diver when descending to a depth of 40 m, assuming that the temperature is constant.

(Atmospheric pressure = 101 kPa)

....

....

....

....

(3)

Is it reasonable to assume that the temperature is constant in this situation? Explain your answer.

....

....

....

....

(2)
(Total 6 marks)

84. Classify each of the terms in the left-hand column by placing a tick in the relevant box.

	Base unit	Derived unit	Base quantity	Derived quantity
Mass				
Charge				
Joule				
Ampere				
Volt				

(Total 5 marks)

85. Complete each of the following statements in words:

The resistance of an ammeter is assumed to be ....

The resistance of a voltmeter is assumed to be ....

(2)

Calculate the total resistance of four 5.0 Ω resistors connected in parallel.

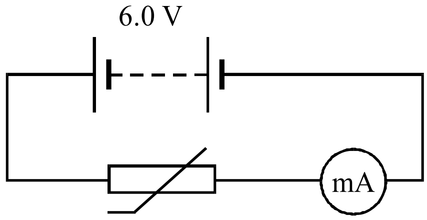
....

....

Total resistance = ...

(2)
(Total 4 marks)

86. A negative temperature coefficient thermistor is used in the following circuit to make a temperature sensor.



Explain how the circuit works.

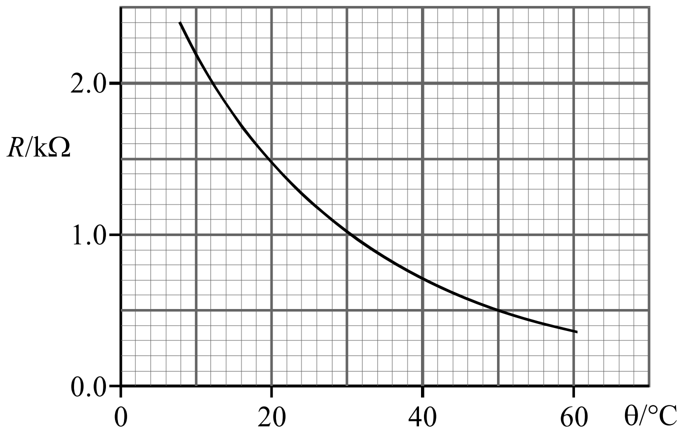
....

....

....

(2)

The graph shows how the resistance of the thermistor varies with temperature.



What will the reading on the milliammeter be when the thermistor is at a temperature of 20 °C?

....

....

....

Milliammeter reading = ...

(3)
(Total 5 marks)

87. A copper wire has a cross-sectional area of 0.20×10^{-6} m^2. Copper has 1.0×10^{29} free electrons per cubic metre.

Calculate the current through the wire when the drift speed of the electrons is 0.94 mm s^{-1}.

....

....

....

Current = ...

(3)

The wire is 4.0 m long. Copper has a resistivity of 1.7×10^{-8} Ω m. Calculate the resistance of the wire.

....

....

....

Resistance = ...

(3)

Calculate the potential difference across the wire.

....

Potential difference = ...

(1)

A second wire with the same dimensions is made from a material that has a greater resistivity than copper. Explain how, if at all, the current will differ from that in the copper wire when the same p.d. is applied across it.

....

....

(2)

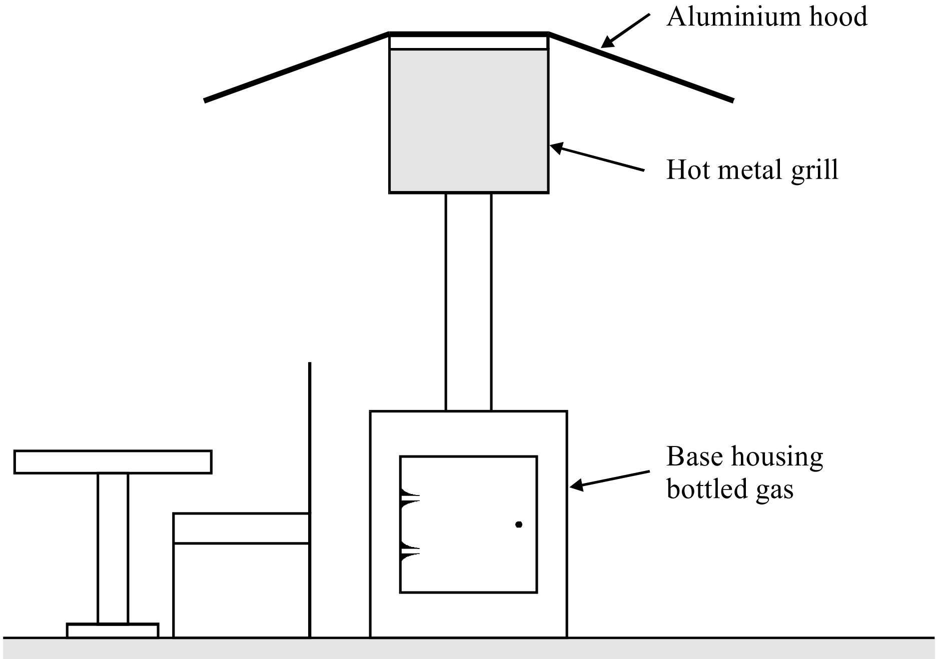
The number of free electrons per cubic metre in this wire is the same as that in the copper wire. Compare the drift velocities of the free electrons in the two wires.

....

....

(1)
(Total 10 marks)

88. A heater, for use outdoors, uses bottled gas to make a metal grill red hot. The metal grill is mounted beneath a polished aluminium hood.



Briefly explain the advantage of having an aluminium hood which is polished on the underside

....

....

on its upper surface ....

....

....

(4)

The bottled gas provides energy for approximately 16 hours when working at 14.4 kW power. Show that the total energy provided during this time is about 800 MJ.

....

....

....

....

(3)

This device is 45% efficient at heating the seating area. Calculate the wasted energy.

....

....

....

Wasted energy = ...

(3)

Explain why the efficiency of the heater will be less than 45% when it is first switched on.

....

....

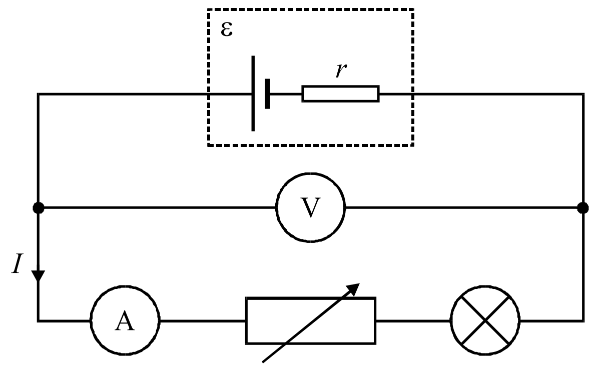
....

....

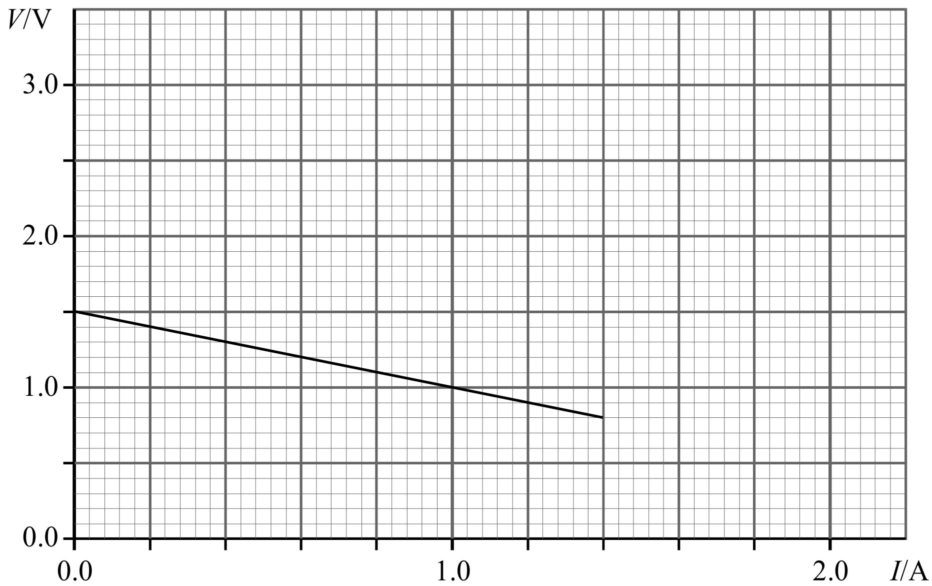
(2)
(Total 12 marks)

89. A student wants to determine the e.m.f. ε of a cell and its internal resistance *r*.

He uses the circuit shown and measures the terminal voltage *V* across the cell and the current *I* in the circuit for each setting of the variable resistor.



He plots the following graph of terminal voltage V against current I.



Show how the relationship $V = \mathcal{E} - Ir$ can be used with his graph to determine the e.m.f. $\mathcal{E}$ of the cell. State its value.

....

....

E.m.f. = ...

(2)

Show how the graph can be used to determine the internal resistance r of the cell. Calculate its value.

....

....

....

Internal resistance = ...

(2)

The student repeats the experiment using two of these cells in series. On the graph, draw the line that he obtains.

(3)

Suggest why the student includes the filament lamp in the circuit.

....

....

(2)
(Total 9 marks)

90. If you want to investigate how the pressure of the gas depends on the volume of the gas, two variables must be kept constant. What are they?

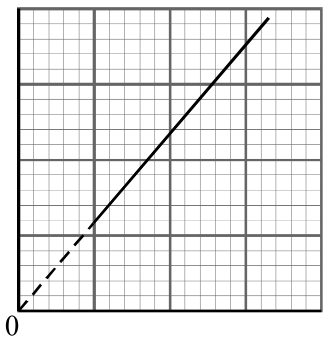
....

....

(2)

Draw a labelled diagram of the apparatus you would use.

(3)



How would you process the readings you have taken in order to produce the graph shown above? Label both axes on the graph.

....

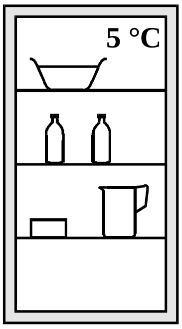
....

....

....

(2)
(Total 7 marks)

91. The contents of a domestic refrigerator are at a constant temperature of 5°C, and the outside surface of the refrigerator is at a constant temperature of 20°C.



Explain how it is possible for the contents of the refrigerator to be at a constant temperature even though energy is continuously flowing in from outside. You may be awarded a mark for the clarity of your answer.

....

....

....

....

(3)

The equation $\Delta U = \Delta Q + \Delta W$ can be applied to the contents of the refrigerator.

What is the value of ΔU? Explain your answer.

....

....

....

(2)

What is meant by ΔQ in this equation?

....

....

....

(2)

Explain why ΔW is zero.

....

....

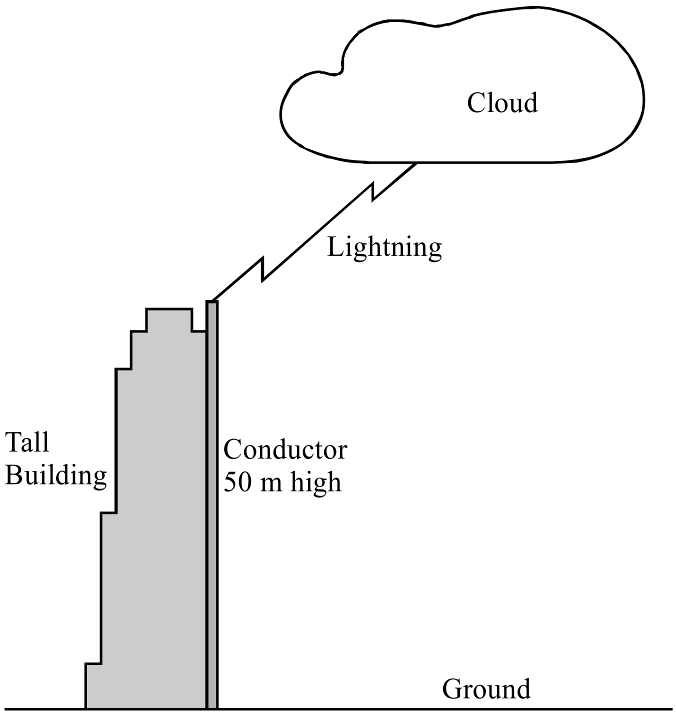
(1)
(Total 8 marks)

92. The table gives four word equations. Complete the table with the quantity defined by each word equation.

Word Equation	Quantity Defined
Voltage ÷ Current	
Voltage × Current	
Charge ÷ Time	
Work Done ÷ Charge	

(Total 4 marks)

93. A lightning stroke passes between a cloud and a lightning conductor attached to a tall building. A very large current of 20 000 A passes for 4.0×10^{-4} s.



Calculate the charge flowing to the ground in this time.

....

....

Charge = ...

(2)

The lightning conductor is 50 m high and has a cross-sectional area of 1.0×10^{-3} m^2.
It is made from copper which has a resistivity of 1.7×10^{-8} Ω m.

Calculate the resistance of the lightning conductor.

....

....

....

Resistance = ...

(3)

Hence calculate the potential difference between the top and bottom of the current-carrying lightning conductor.

....

....

Potential difference = ...

(2)

If lightning strikes a tree such that there is the same current through it as there was through the conductor, then a much larger potential difference exists between the top and bottom of the tree. Explain why this is so.

....

....

(1)
(Total 8 marks)

94. A car of weight 12 000 N is stationary on a horizontal road. The four wheels of the car are fitted with air-filled (pneumatic) tyres. The pressure of the air in each tyre is 3.0×10^5 Nm^{-2}.

Estimate the area of contact between each tyre and the road surface.

....

....

....

Area of contact = ...

(2)

The rubber in the tyres is repeatedly stretched and relaxed when the car is in motion but the overall volume of the tyres remains constant. During a journey the temperature of the air in the tyres rises from 10 °C to 30 °C. Calculate the pressure of the air at 30 °C.

....

....

....

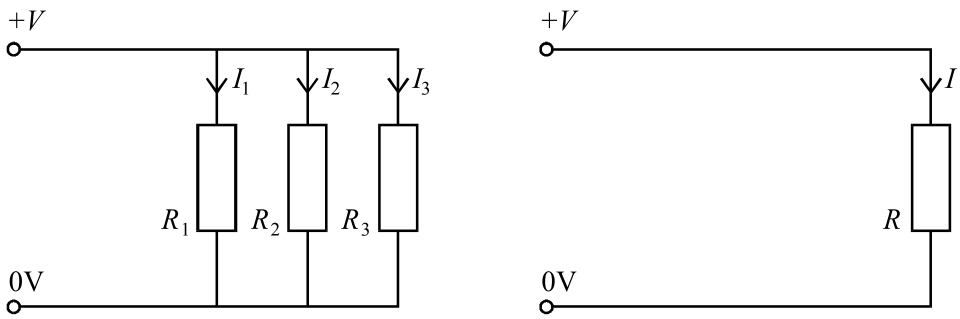
Pressure = ...

(3)

Sketch a graph below to show how the area of contact between a tyre and the road varies with the pressure of the air.

(3)
(Total 8 marks)

95. Three resistors R_1, R_2 and R_3 are connected in parallel with each other. They could be replaced by a single resistor of resistance R.



Show that the resistance, R, of the equivalent resistor can be calculated from

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

....

....

....

....

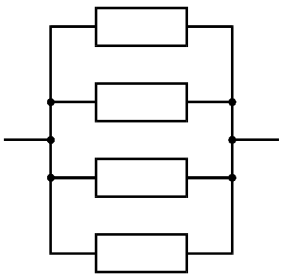
....

....

(3)

A student has four identical resistors each of resistance 10 Ω. She connects them to form the different networks shown below.

Calculate the equivalent total resistance of each network.



First network

....

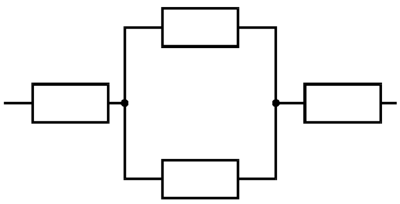
....

....

....

....

Total resistance = ...Ω



Second network

....

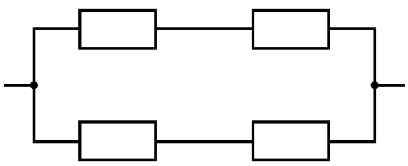
....

....

....

....

Total resistance = ...Ω



Third network

....

....

....

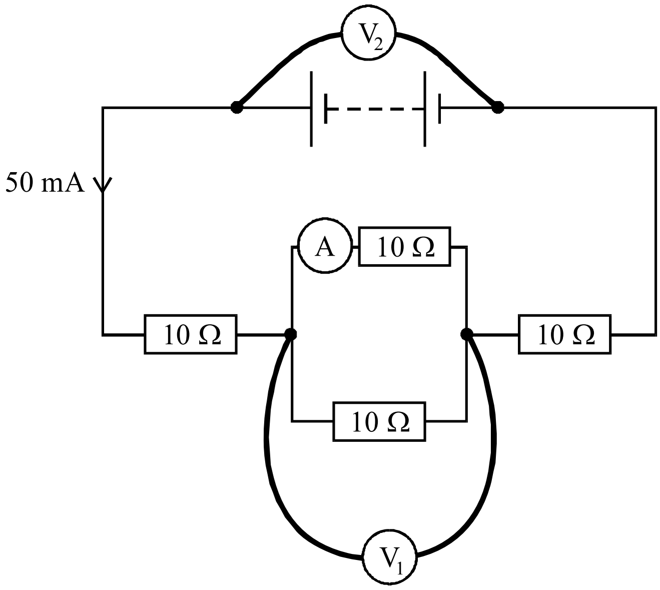
....

....

Total resistance = ...Ω

(3)

She then connects a battery across the second network and adds meters to make the circuit shown below. A current of 50 mA is drawn from the battery.



Determine the reading on each of the three meters.

Reading on ammeter A:

....

Ammeter reading = ... mA

Reading on voltmeter V_1:

....

Voltmeter reading = ... V

Reading on voltmeter $V_{2:}$

....

....

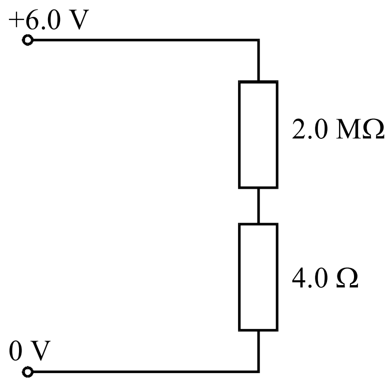
Voltmeter reading = ... V

(5)

(Total 11 marks)

96. Two resistors of resistance 2.0 MΩ and 4.0 Ω are connected in series across a supply voltage of 6.0 V. Together they form a simple potential divider circuit.

State the potential difference across each resistor.

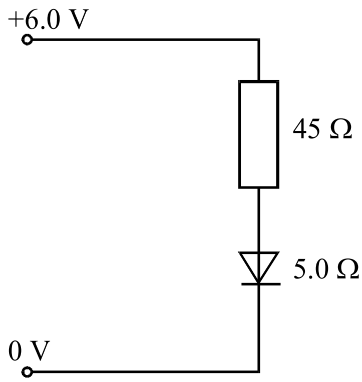


P.d. across the 2.0 MΩ resistor = ...

P.d. across the 4.0 Ω resistor = ...

(2)

A second potential divider circuit uses a resistor and a diode connected in series with the same supply. Calculate the potential difference across each component when the resistance of the resistor and diode are 45 Ω and 5.0 Ω respectively.



....

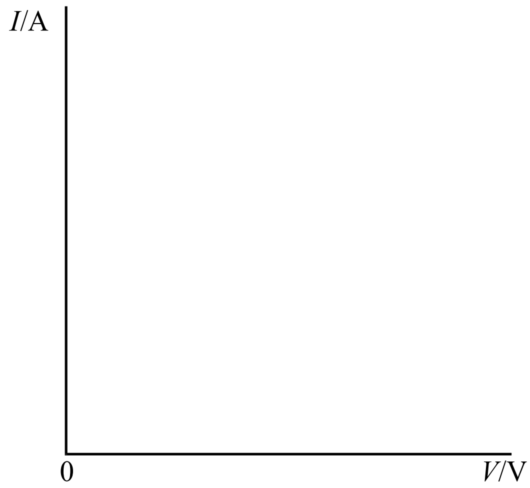
P.d. across the 45 Ω resistor = ...

....

P.d. across the diode = ...

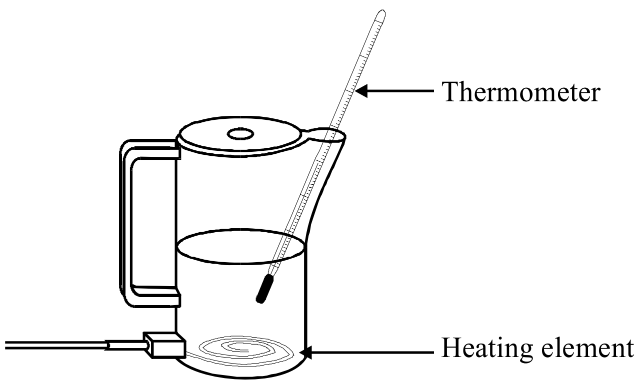
(2)

In this circuit the diode is in forward bias. Use the axes below to sketch a graph of current I against potential difference V for a diode in forward bias.



(1)
(Total 5 marks)

97. Water in a plastic kettle is heated by an electric element near the bottom of the kettle. The temperature of the water near its surface can be recorded on a thermometer.



A kettle contains 0.70 kg of water at an initial temperature of 20°C. It is calculated that about 250 kJ of thermal energy is needed to heat the water from 20°C to 100°C. Show how this value is calculated.

(The specific heat capacity of water is 4200 J kg^{-1} K^{-1}.)

....

....

....

(2)

Calculate the time it should take for an element rated at 2.2 kW to supply this energy.

....

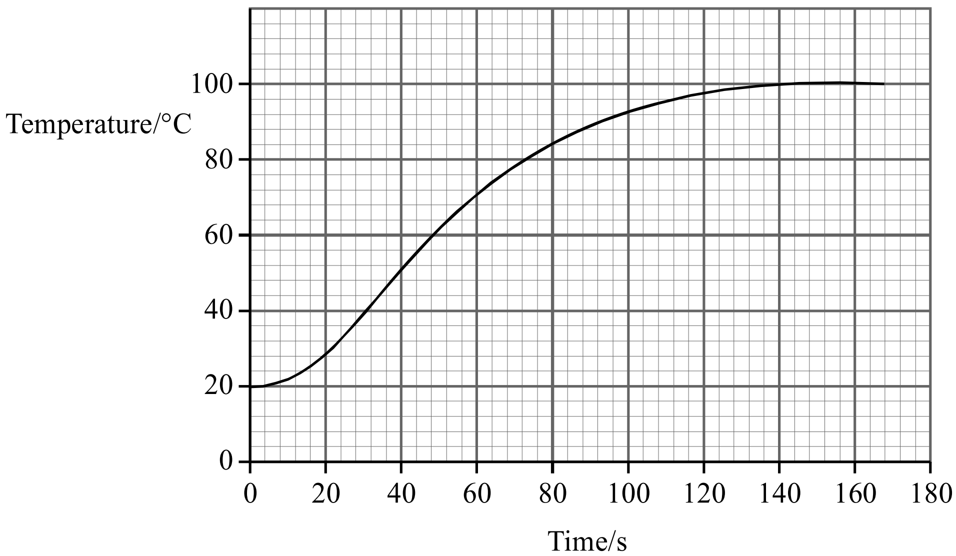
....

....

Time = ...

(3)

To check this calculation, the kettle is switched on at t = 0 s and temperature readings are taken as the water is heated. The graph shows how the temperature varies with time.



Use the graph to fully describe qualitatively how the temperature of the water changes during the first 160 s.

....

....

....

....

(3)

Estimate the efficiency of the electric heating element in bringing the water to the boil.

....

....

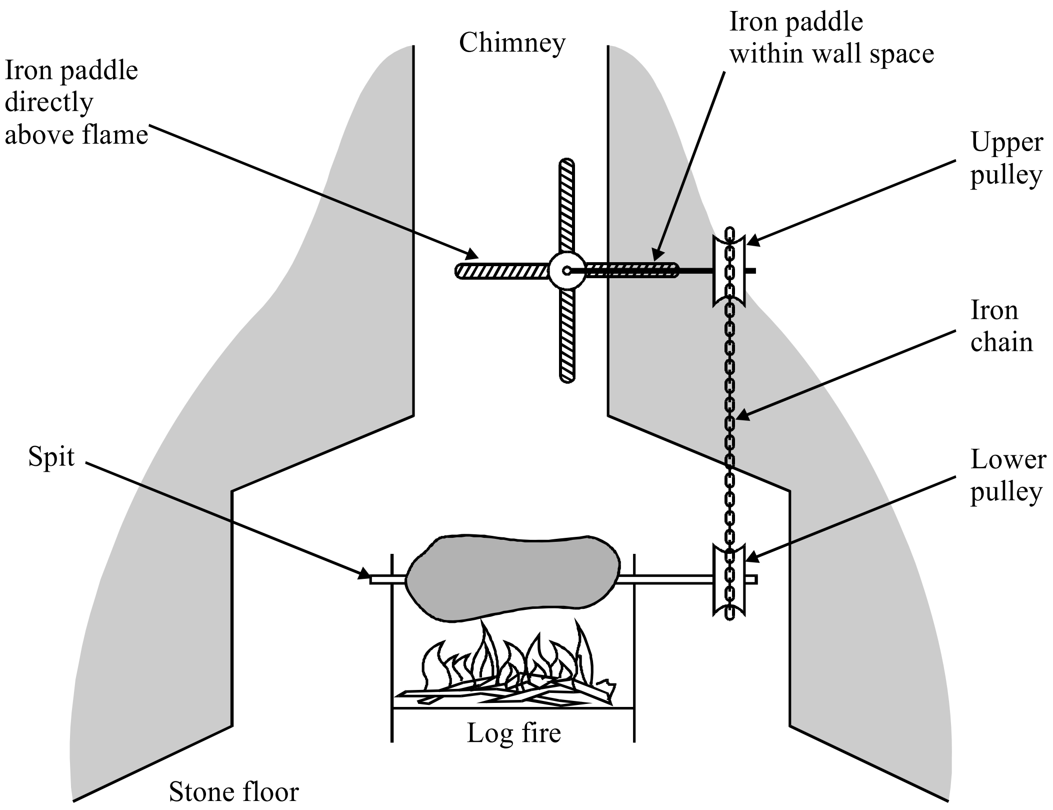
....

Efficiency = ...

(2)
(Total 10 marks)

98. A Smoke Jack is an example of an 18th century heat engine that was found in the large kitchens of manor houses and stately homes. It consists of four rotating paddles, which are in the chimney, directly above the open log fire. The paddles are connected to the spit by gears and pulleys. Food on the spit is slowly cooked as the spit rotates.

A diagram of a simple Smoke Jack is shown below.



Define the term **heat engine**.

....

....

....

(3)

During a cold winter, the temperature of the air at the top of the chimney is –5 °C and that of the hot air just above the flames is at 350 °C. Calculate the maximum thermal efficiency of this Smoke Jack.

....

....

....

Maximum thermal efficiency = ...

(3)

In practice, the Smoke Jack's thermal efficiency is much less than this. With reference to the diagram state two different ways by which the thermal energy from the logs would be wasted.

1 ....

....

2 ....

....

(2)

The molecules of the gases in the air are in constant random motion and so possess random kinetic energy. It can be assumed that these gases behave as ideal gases.

Hence calculate the ratio of the average kinetic energy of the molecules just above the flames to that of the molecules at the top of the chimney.

....

....

Ratio = ...

(2)
(Total 10 marks)

99. The kinetic theory of gases is based on a number of assumptions. Two of these are stated below.

First assumption: The molecules are in continuous, random motion.

Second assumption: The average distance between the molecules is much larger than the molecular diameter.

State and explain one observation which supports each assumption.

First assumption

....

....

....

....

....

(2)

Second assumption

....

....

....

....

....

(2)
(Total 4 marks)

100. State the unit of the base quantity **current.**

....

(1)

Determine the base units of **potential difference.**

....

....

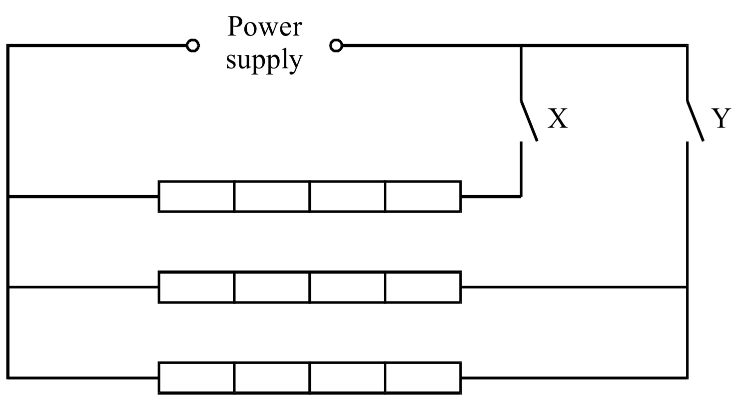
....

....

....

(3)
(Total 4 marks)

101. An electric room heater consists of three heating elements connected in parallel across a power supply.



Each element is made from a metal wire of resistivity 5.5×10^{-5} Ω m at room temperature. The wire has a cross-sectional area 8.0×10^{-7} m^2 and length 0.65 m.

The heater is controlled by two switches, X and Y.

Show that the resistance of one heating element at room temperature is approximately 45 Ω.

....

....

....

(3)

Calculate the total resistance of the heater for the following combinations of switches at the moment the switches are closed.

Switch X	**Switch Y**	**Resistance of heater / Ω**
Open	Closed	
Closed	Open	
Closed	Closed	

(3)

Calculate the maximum power output from the heater immediately it is connected to a 230 V supply.

....

....

Maximum power = ...

(2)

After being connected to the supply for a few minutes the power output falls to a lower steady value. Explain why this happens.

....

....

....

....

(2)
(Total 10 marks)

102. A thick wire is connected **in series** with a thin wire of the same material and a battery.

In which wire do the electrons have the greater drift velocity? Explain your answer.

....

....

....

....

....

(3)

A battery is connected across a large resistor and a small resistor is connected **in parallel.** The currents through the resistors are different.

Which resistor has the higher dissipation of power? Explain your answer.

....

....

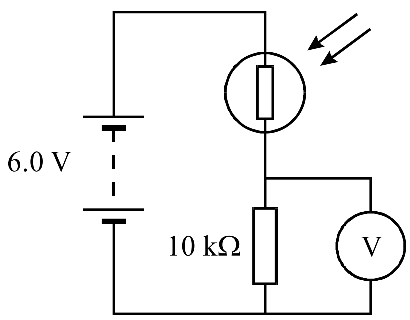
....

....

....

(3)
(Total 6 marks)

103. The following circuit can be used as a lightmeter.



The maximum value of resistance of the light-dependent resistor (LDR) is 950 kΩ.
What is the reading on the voltmeter for this resistance?

....

....

....

Voltmeter reading = ...

The minimum value of resistance of the LDR is 1.0 kΩ. What is the reading on the voltmeter for this resistance?

....

....

....

Voltmeter reading = ...

(3)

For this lightmeter the voltmeter is connected across the 10 kΩ resistor, rather than the LDR. Explain how the readings on the voltmeter enable this circuit to be used as a lightmeter.

....

....

....

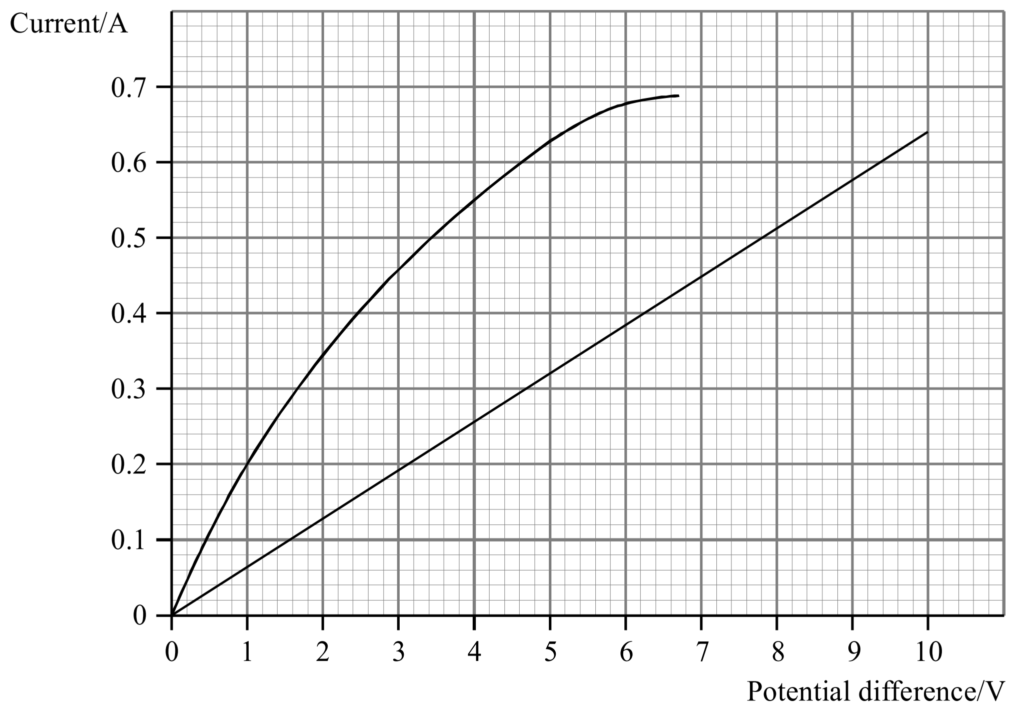
....

(2)
(Total 5 marks)

104. A student investigates how the current in a resistor varies as the potential difference across the resistor is varied. Draw a suitable circuit diagram for the investigation.

(3)

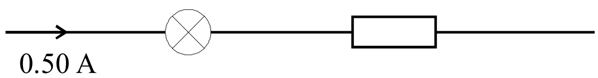
The graphs show the variation of current with potential difference for a filament lamp and for an ohmic resistor.



Label one graph **lamp** and the other graph **resistor.**

(1)

The lamp and resistor are connected in series as shown. There is a current of 0.50 A.



Use the graph to find the total potential difference across the combination.

....

....

....

....

Potential difference = ...

(2)

What is the resistance of the lamp under these conditions?

....

....

Resistance = ...

(2)
(Total 8 marks)

105. Define the term **specific latent heat of fusion**.

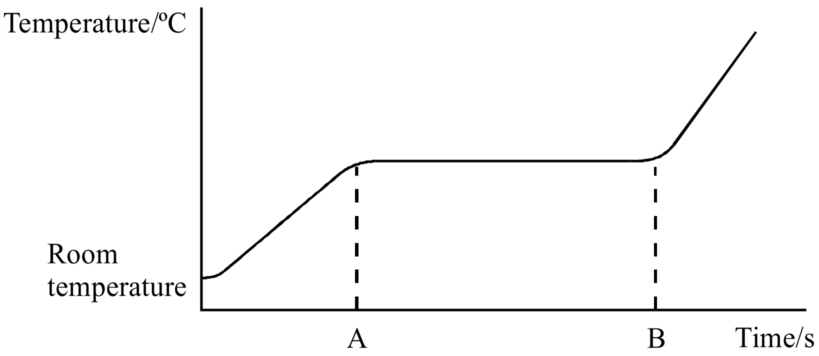
....

....

....

(3)

The graph shows how the temperature of a heated metal sample varies with time.



During the time interval AB, the metal changes from a solid to a liquid whilst still being heated. Explain, in molecular terms, what is happening to the energy being supplied during this time.

....

....

(1)

Describe, in molecular terms, the main differences between the solid and liquid states. You may illustrate your answer with simple diagrams.

....

....

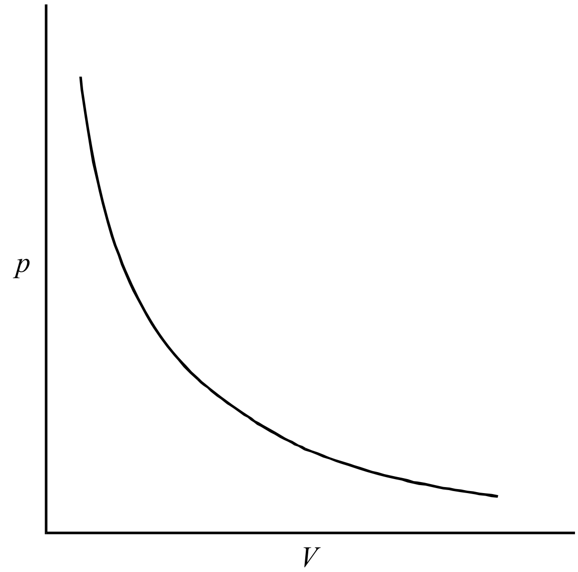
....

....

....

(2)
(Total 6 marks)

106. The graph shows the relationship between the pressure p and the volume V of a fixed mass of dry air.

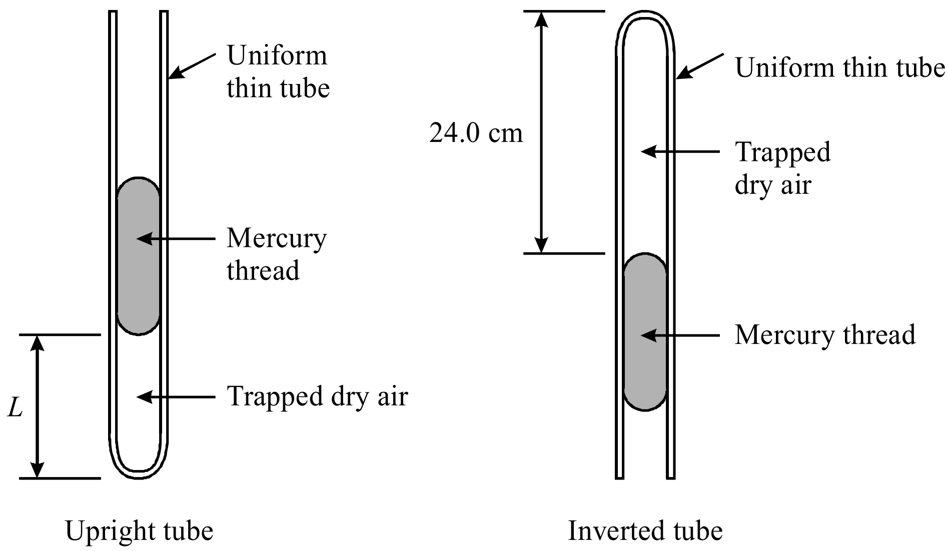


Write down the formula for this relationship.

....

(1)

A uniform thin tube, sealed at one end, contains a thread of mercury which traps a column of dry air. The other end of the tube is open to the atmosphere.



The length of the column of air changes when the tube is inverted. In each case the thread of mercury exerts a pressure of 0.20×10^5 Pa and atmospheric pressure is 1.00×10^5 Pa.

What is the pressure of the trapped dry air

(i) when the tube is upright?

....

Dry air pressure = ...

(ii) when the tube is inverted?

....

Dry air pressure = ...

(2)

The final length of the column of air is 24.0 cm. Calculate the initial length L in centimetres, when the tube is upright.

....

....

....

L = ...

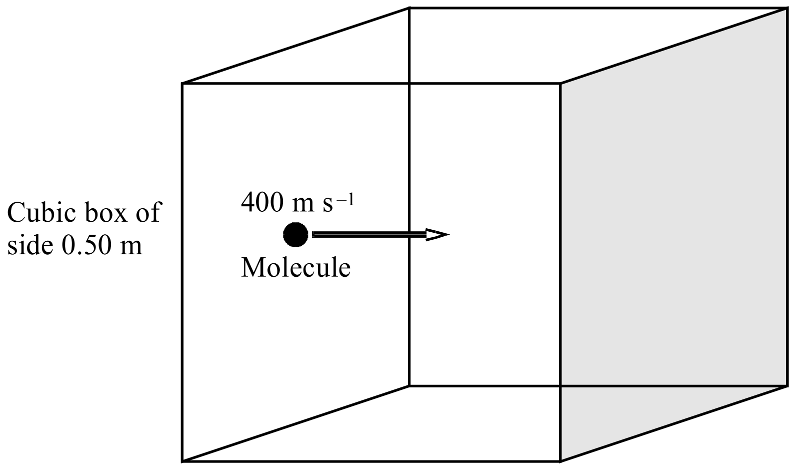
(3)

What assumption did you make about the dry air?

....

(1)
(Total 7 marks)

107. A cubic box with sides of length 0.50 m contains a gas. There are 1.5×10^{24} molecules inside the box.



A molecule is moving at 400 m s^{-1} in a direction perpendicular to the shaded face.
The average rate of change of momentum for this molecule at the shaded face is 1.6×10^{-20} kg m s^{-2}.

State the two assumptions that the kinetic theory makes about the collisions of this molecule with the shaded face.

....

....

....

(2)

One third of all the molecules strike the shaded face. Calculate the average force exerted by these molecules if their average speed is 400 m s^{-1}.

....

....

....

Average force = ...

(3)

Hence calculate the gas pressure on the shaded face.

....

....

Gas pressure = ...

(2)

The formula from kinetic theory for the pressure exerted by a gas is given by

$$p = \frac{1}{3}\rho\langle c^2\rangle$$

State what the term $\langle c^2\rangle$ represents.

....

(1)
(Total 8 marks)

108. Outline the principle of operation of a heat engine. You may be awarded a mark for the clarity of your answer.

....

....

....

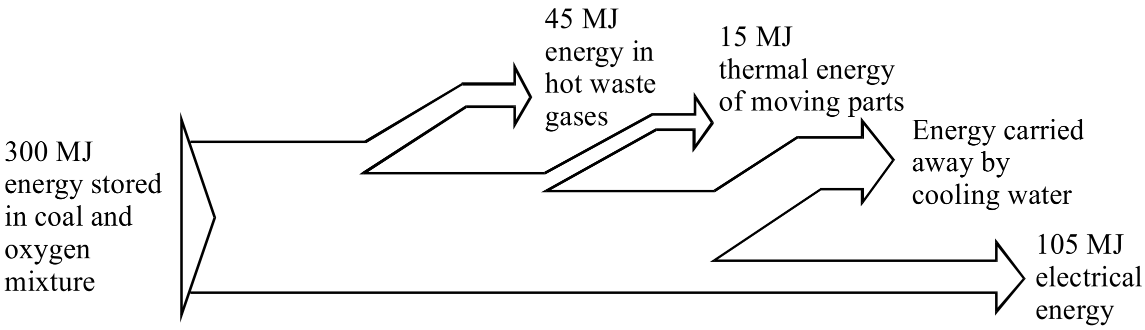
....

....

....

(4)

The diagram shows the energy flow for a typical coal-fired power station.



Calculate how much energy is carried away by the cooling water.

....

....

Energy = ...

(1)

Calculate the efficiency of the power station.

....

....

Efficiency = ...

(1)

(Total 6 marks)

109. A student is provided with two filament lamps A and B. Each is rated 12 V 60 W, but lamp A has a carbon filament and lamp B a tungsten filament.

Calculate the resistance of each filament lamp under normal operating conditions.

....

....

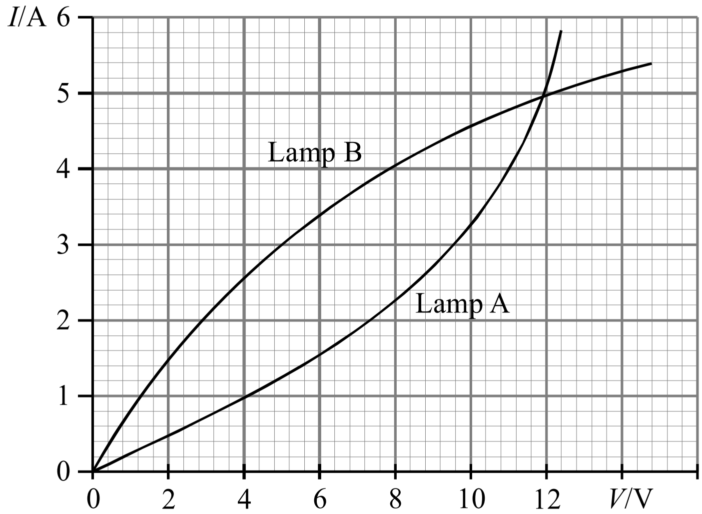
....

....

Resistance = ...

(3)

The graph shows the relationship between the current I and the potential difference V for the two filament lamps.



Describe how the resistances of lamp A and lamp B vary with current.

Lamp A: ....

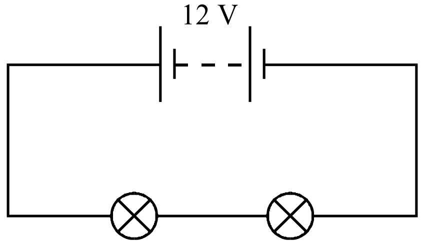
....

Lamp B: ....

....

(2)

The diagram shows the two filament lamps connected in series across a battery of e.m.f 12 V and negligible internal resistance. Both filaments glow dimly, but the *hlank* filament of lamp A is the brighter.



Why does each filament glow only dimly?

....

....

....

(1)

Suggest why the filament of lamp A is the brighter.

....

....

....

(2)
(Total 8 marks)

110. Complete the table by selecting a typical value for each physical quantity from the list below. Each value may be used once, more than once or not at all.

0.05 Ω	0.3 mm s^{-1}	2.0×10^{-8} Ωm	300 K
6.0 Ω	30 cm s^{-1}	2.0×10^{15} Ωm	3000 K
2 kΩ			
10 MΩ			

Physical quantity	Typical value
Resistance of a voltmeter	
Internal resistance of a car battery	
Internal resistance of an e.h.t. supply	
Resistivity of an insulator	
Drift velocity of electrons in a metallic conductor	
Temperature of a working filament bulb	

(Total 6 marks)

111. A 500 W electric toaster operates from the 230 V mains. Calculate the current in the heating element of the toaster.

....

....

....

....

Current = ...

(3)

The heating element of the toaster is made of much thinner wire than the wire in its supply cable. In which of these two wires do the electrons have the greater drift velocity?

....

(1)

Explain your answer. You may be awarded a mark for the clarity of your answer.

....

....

....

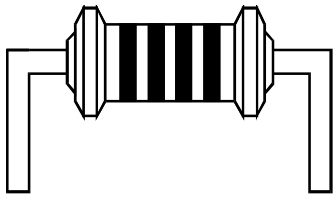
....

....

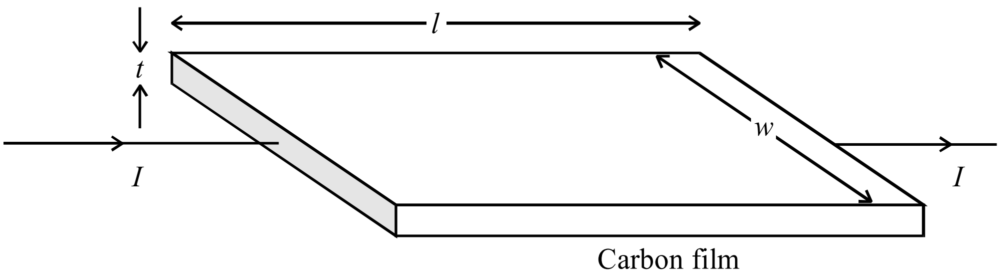
....

(4)
(Total 8 marks)

112. The diagram shows a type of resistor commonly used in electronic circuits.



It consists of a thin film of carbon wrapped around a cylindrical insulator. The diagram below (not to scale) shows a typical **film** of carbon, resistivity ρ, before it is wrapped round the insulator.



Show that the resistance R of the carbon film is given by

$$R = \frac{\rho l}{wt}$$

....

....

....

(2)

This film has length l = 8.0 mm, width w = 3.0 mm and thickness t = 0.0010 mm (i.e. $t = 1.0 \times 10^{-6}$ m). If the resistivity of carbon is $6.0 \times 10^{-5}\,\Omega$m, calculate the resistance of the carbon film.

....

....

....

....

....

Resistance = ...

(3)

Show that the resistance of a square piece of carbon film of uniform thickness is independent of the length of the sides of the square.

....

....

....

....

(2)
(Total 7 marks)

113. Define the term **specific heat capacity**.

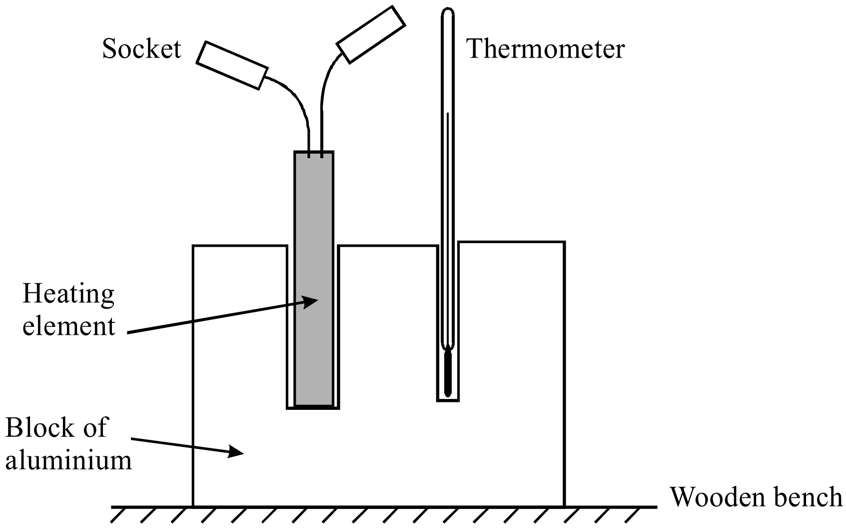
....

....

....

(2)

A student decides to measure the specific heat capacity of aluminium by an electrical method. He selects his apparatus and then assembles the aluminium block, the thermometer and the heating element as shown.



The student intends to substitute his results into the relationship

$$mc\Delta T = VIt$$

Draw a diagram of the electrical circuit he would need to set up in order to be able to carry out the experiment.

(3)

What other pieces of apparatus would he need?

....

....

(2)

He carries out the experiment and then calculates his value for the specific heat capacity of aluminium. He discovers that his value is higher than the accepted value of 900 J kg^{-1} K^{-1}.

Suggest why his result is higher than 900 J kg^{-1} K^{-1}.

....

....

(1)

With reference to the apparatus shown in the diagram, state two modifications that he should make in order to minimise the discrepancy.

1. ....

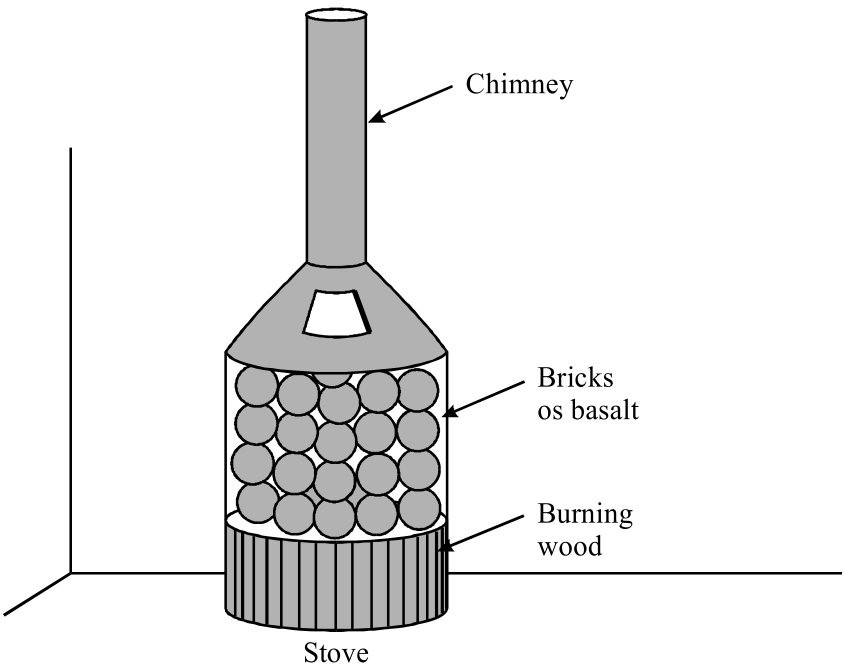
....

2. ....

....

(2)
(Total 10 marks)

114. A sauna is a room in which there is a stove containing very hot bricks of basalt over which water is poured.



Before use the basalt is tested for resistance to cracking by first heating the bricks to 750°C and then dropping them into cold water.

Each brick has a mass of 1.4 kg and an initial temperature of 22 °C. Each receives 860 kJ of energy from the burning wood. Show that the specific heat capacity of basalt is approximately 850 J kg^{-1} K^{-1}.

....

....

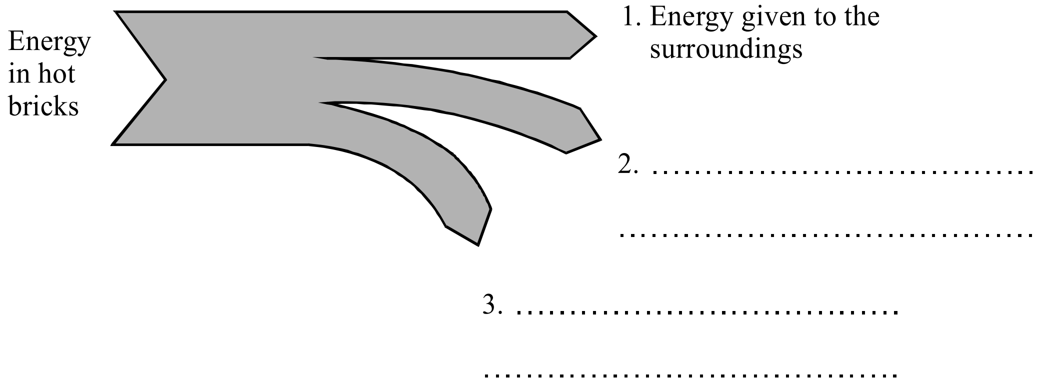
....

....

(3)

When several hot bricks are dropped into a trough of cold water, steam is immediately produced. After a short time the temperature of the water rises to a steady value. Some of the energy is used to heat the surroundings, as shown in the energy-flow diagram.

Add labels to the other arms of the diagram.



(2)
(Total 5 marks)

115. Write down the ideal gas equation.

....

....

(1)

Use your equation to give the unit for the molar gas constant in SI base units.

....

....

....

(2)

The pressure p of a gas is related to its density p and the mean square molecular speed $\langle c^2 \rangle$ by the formula

$$p = \frac{1}{3}\rho\langle c^2 \rangle$$

Use this relationship and the ideal gas equation to show that the average kinetic energy of a molecule is proportional to the kelvin temperature of the gas.

....

....

....

....

....

(3)

Sketch a graph to show how the product pV (pressure × volume) varies with temperature in °C for one mole of ideal gas.

Comment on any significant features of your graph.

....

....

....

....

....

(4)
(Total 10 marks)

116. Define the term **e.m.f. of a cell**.

....

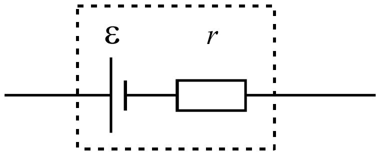
....

....

(2)

A student wants to use a graphical method to determine the internal resistance r of a cell of known e.m.f. $\mathcal{E}$.

Complete the diagram below showing how the cell should be connected in a circuit to allow the student to do this.



(2)

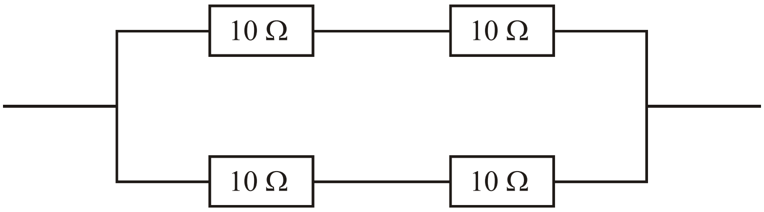
Sketch the graph the student should plot and state how she could determine *r* from the graph.

....

....

(2)
(Total 6 marks)

117. Four 10 Ω resistors are connected as shown in the diagram.



Calculate the total resistance of the combination.

....

....

....

....

Total resistance = ...

(3)

Comment on your answer and suggest why such a combination of resistors might be used.

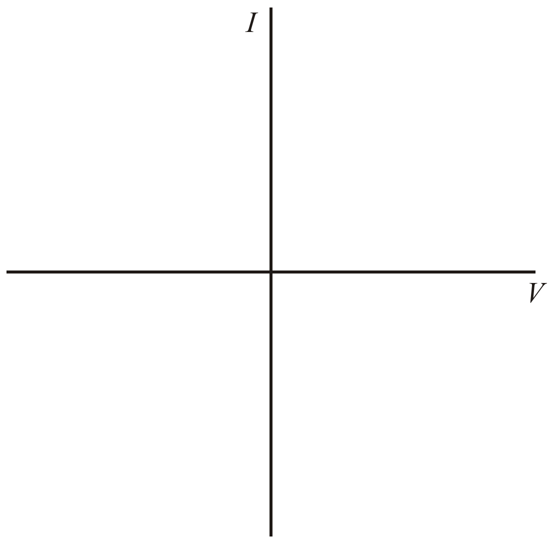
....

....

....

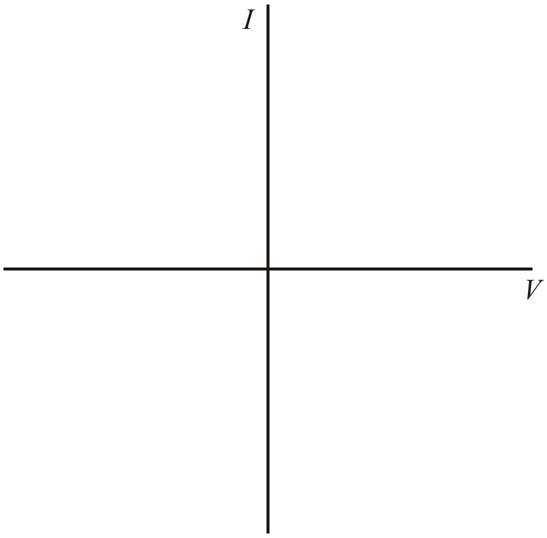
(2)
(Total 5 marks)

118. Use the axes to draw the current-voltage characteristic of a diode.



(3)

Use the axes to draw the current-voltage characteristic of a filament lamp.



(3)
(Total 6 marks)

119. A cell of negligible internal resistance is connected in series with a microammeter of negligible resistance and two resistors of value 15 kΩ and 25 kΩ. The current is 150 µA.
Draw a circuit diagram of the arrangement.

(1)

Show that the e.m.f. of the cell is 6.0 V.

....

....

....

(2)

A voltmeter is now connected in parallel with the 25 kΩ resistor. Draw a diagram of the new circuit.

(1)

When the voltmeter is connected the reading on the microammeter increases to 170 μA. Calculate the resistance of the voltmeter.

....

....

....

....

....

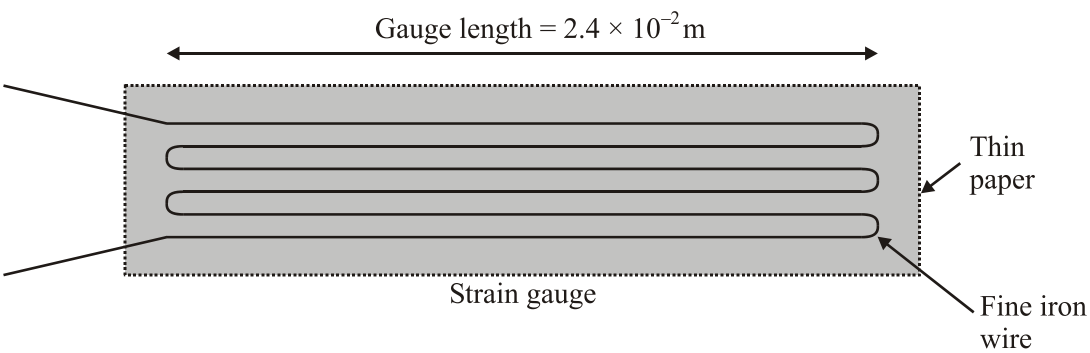
....

....

Resistance = ...

(3)
(Total 7 marks)

120. Lord Kelvin discovered that the electrical resistance of iron wire changed when the wire was stretched or compressed. This is the principle on which a resistance strain gauge is based. Such a gauge consists of a length of very fine iron wire cemented between two very thin sheets of paper.



Strain gauge

The cross-sectional area of the wire is 1.1×10^{-7} m^2 and the gauge length as shown in the diagram is 2.4×10^{-2} m. The resistivity of iron is 9.9×10^{-8} Ω m. Calculate the resistance of the strain gauge.

....

....

....

....

Resistance of strain gauge = ...

(4)

When this gauge is stretched its length is increased by 0.1% but its cross-sectional area remains the same. What is the change in the resistance of the gauge?

....

....

Change in resistance = ...

(2)

Explain the effect that stretching the wire will have on the drift velocity of electrons in the wire. Assume that the other physical dimensions of the wire remain unchanged and that there is a constant potential difference across the wire.

....

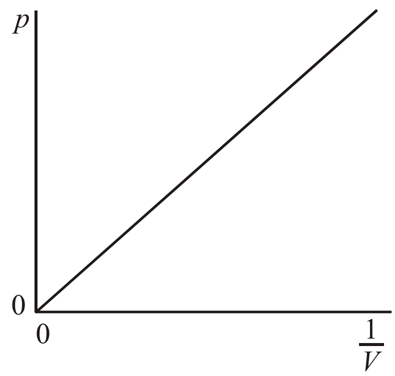
....

....

....

(3)
(Total 9 marks)

121. An experiment was carried out on the behaviour of a fixed mass of gas. Measurements were taken of the pressure p exerted by the gas and its volume V. The following graph was plotted.



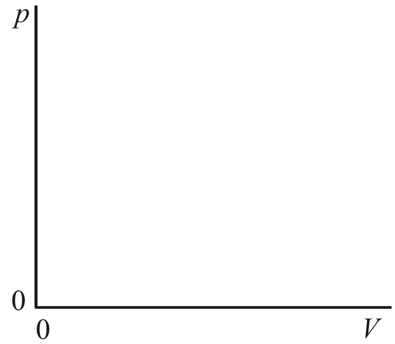
State, in words, the relationship represented by this graph.

....

....

(2)

On the axes below sketch the graph that would be obtained if pressure were plotted against volume.



(2)

The ideal gas equation is

$$pV = nRT$$

Show that the product pV has the same units as energy.

....

....

....

(2)

Explain, in terms of the kinetic model, how the molecules of a gas exert a pressure.
You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

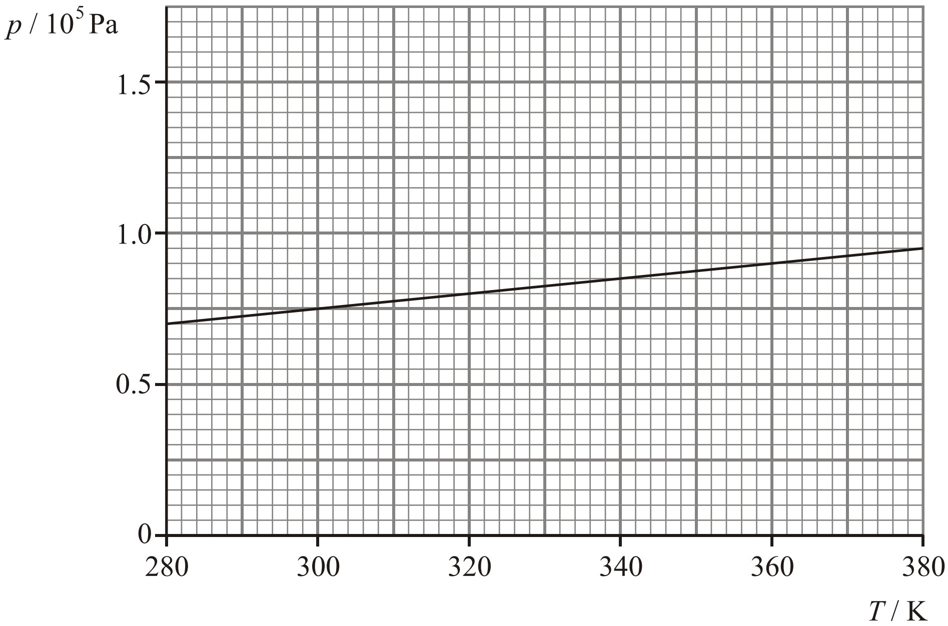
....

....

....

(5)
(Total 11 marks)

122. A student has a sample of 0.50 mol of oxygen in a flask of capacity 0.016 m^3.
He measures the pressure p exerted by the oxygen for a wide range of temperatures T.
He then plots a graph of his results.



Use the graph to determine his value for the molar gas constant R.

....

....

....

....

....

R = ...

(3)

The student repeats the experiment using the same range of temperatures with the same sample of oxygen but uses a flask that has twice the volume of the original.

Draw on the graph the result of this experiment.

(3)
(Total 6 marks)

123. You are asked to measure the specific heat capacity of aluminium using a cylindrical block of aluminium that has been drilled out to hold an electrical heater and a thermometer.
Draw a diagram of the apparatus, including the electrical circuit, which you would use.

(3)

List the measurements you would take.

....

....

....

....

....

....

(4)

Explain how you would use these measurements to find the specific heat capacity of aluminium.
State any assumptions you have made.

....

....

....

....

....

....

(3)
(Total 10 marks)

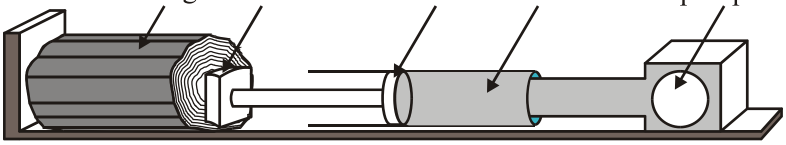
124. The hydraulic principle is often used in the design of machinery for applying large forces. What is the advantage to the user of such a machine?

....

....

(1)

The machine shown below uses the hydraulic principle to cut logs. It has an electrically powered pump that is used to vary the pressure on the oil.



The cutter exerts a force of 1.7×10^6 N on the log and the piston has a cross-sectional area of 7.8×10^{-3} m^2. Calculate the pressure exerted by the pump.

....

....

Pressure = ...

(2)

What assumption have you made in your calculation?

....

(1)

On average it takes 20 s to push the cutter 60 cm through a log. Calculate the power output of the machine.

....

....

Power output = ...

(2)

(Total 6 marks)

125. State the word equation that is used to define charge.

....

....

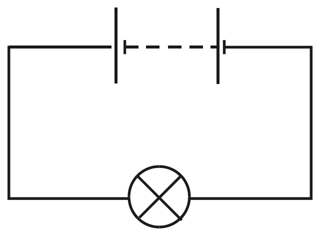
(1)

Define potential difference.

……………………………………………………………………………………………………

…………………………………………………………………………………………………… **(1)**

A 9.0 V battery of negligible internal resistance is connected to a light bulb.



Calculate the energy transferred in the light bulb when 20 C of charge flows through it.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

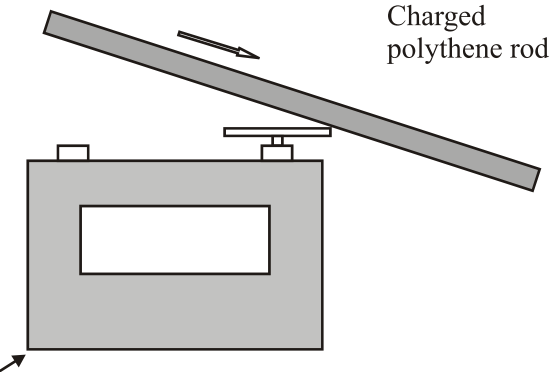
……………………………………………………………………………………………………

Energy = ...

(2)

(Total 4 marks)

126. A polythene rod was negatively charged by rubbing it with a cloth. The rod was then stroked several times across the metal cap of a meter used for measuring charge.



The initial reading on the meter was zero.

After 3.8 s the final reading was -6.4×10^{-8} C.

Calculate the number of electrons that were transferred to the metal cap.

………………………………………………………………………………………………

………………………………………………………………………………………………

Number of electrons = …………………………

(3)

Calculate the average rate in C s^{-1} at which charge was transferred to the metal cap.

………………………………………………………………………………………………

………………………………………………………………………………………………

Rate = …………………………………… C s^{-1}

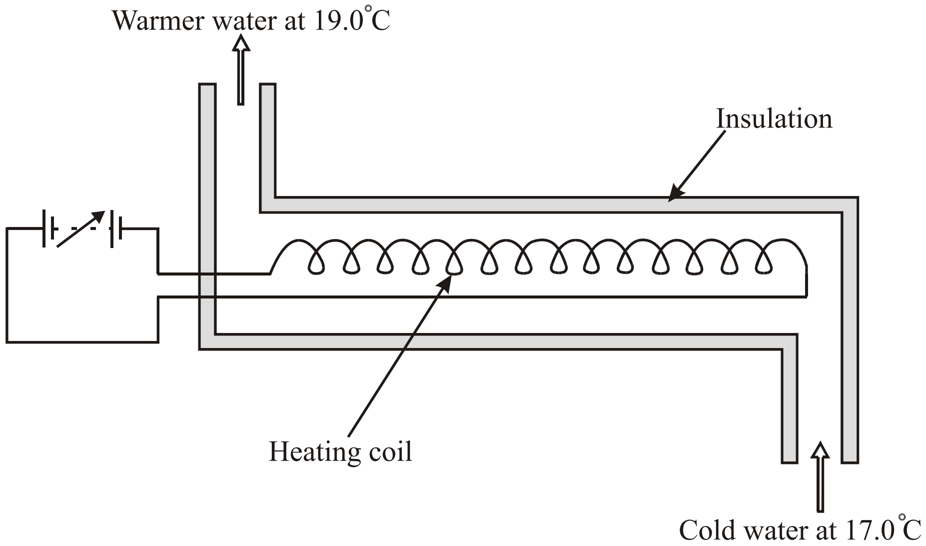
(2)

State the base unit for the rate of flow of charge.

………………………………………………………………………………………………

(1)
(Total 6 marks)

127. A heating coil is used to warm water that flows past it at a steady rate of 0.24 kg s^{-1}. The heating coil remains at a constant working temperature of 350 °C.



The specific heat capacity of water is 4200 J kg^{-1} K^{-1}. Calculate the rate of absorption of energy by the cold water assuming no energy is lost to the surroundings.

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……………………………………………………………………………………………………

……………………………………………………………………………………………………

Rate of absorption = ...

(3)

The heating coil is operating at its normal working temperature of 350 °C. The equation $\Delta U = \Delta Q + \Delta W$ may be applied **to the coil**. State and explain the **value** of each quantity for each second of operation.

ΔU = ...

Reason ....

....

ΔQ = ...

Reason ....

....

ΔW = ...

Reason ....

....

(6)
(Total 9 marks)

128. The **increase** in pressure Δp as you go down a distance Δh in a liquid of density ρ is given by the formula

$$\Delta p = \rho g \Delta h$$

where g has its usual meaning.

Show that this equation is homogeneous with respect to units.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

(3)

A diver at a depth of 30.0 m in the Dead Sea releases an air bubble of volume 2.00 cm^3. Calculate the volume of the bubble in cm^3 when it reaches the surface of the sea, assuming the temperature of the air in the bubble remains constant.

Density of the water in the Dead Sea = 1170 kg m^{-3}.
Atmospheric pressure = 101 kPa.

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……………………………………………………………………………………………………

……………………………………………………………………………………………………

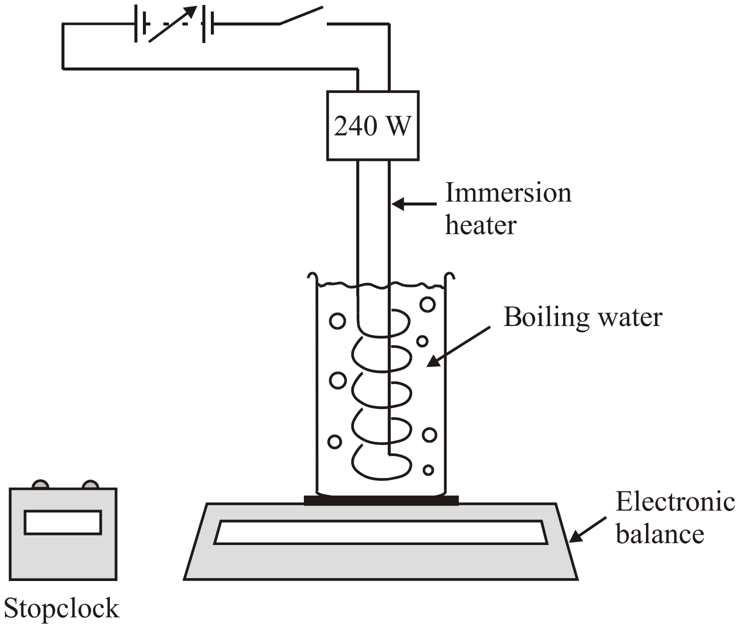
……………………………………………………………………………………………………

……………………………………………………………………………………………………

Volume = ... cm^3

(4)
(Total 7 marks)

129. A student uses the apparatus shown to determine a value for the specific latent heat of vaporisation of water l_v.



Define the term **specific latent heat of vaporisation**.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

(3)

The student uses an immersion heater to bring the water to a vigorous boil and then takes readings to enable him to calculate the mass of water that changes state in 285 s. He tabulates his results.

Power rating of heater, P	240 W
Initial reading on balance, m_1	301 g
Final reading on balance, m_2	265 g
Reading on stop-clock, t	285 s

Calculate the energy provided by the immersion heater during the 285 seconds.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Energy = ...

(2)

Hence show that his value for the specific latent heat of vaporisation of water l_v is approximately 2×10^6 J kg^{-1}.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

(2)

The student decides that he can improve his results by placing a lid partially over the beaker so that boiling water cannot spill but steam can still escape. Suggest and explain how this modification might affect his value for l_v. You may be awarded a mark for the clarity of your answer.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

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……………………………………………………………………………………………………

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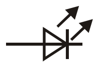
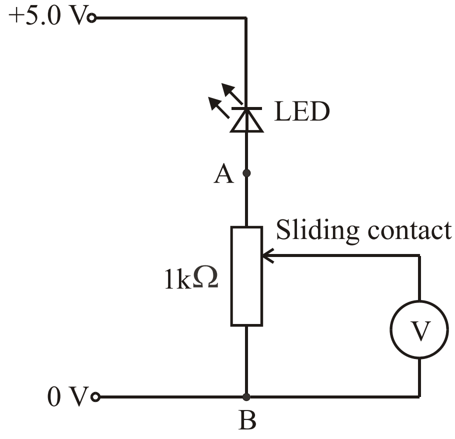
(4)
(Total 11 marks)

130. A light-emitting diode (LED) is a diode that emits light when it conducts. Its circuit symbol is



A student connects the circuit shown below.



She notices that the reading on the high resistance voltmeter remains at 0 V as she slides the contact between terminals A and B.

Explain this observation as fully as you can.

……

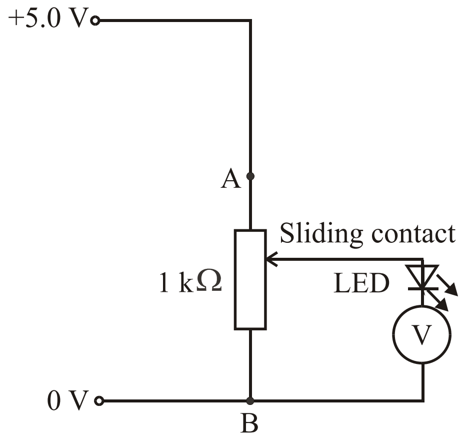
……

……

……

(2)

The student then disconnects the LED and reconnects the circuit as shown below. She intends to vary the intensity of the light emitted by the LED by sliding the contact between terminals A and B.



The student cannot detect any light emitted by the LED. Briefly explain why the LED is so dim.

………

………

………

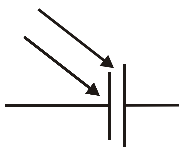
………
(2)

Draw the circuit that the student should have connected using this apparatus in order to vary the brightness of the LED and measure the potential difference across it.

(3)
(Total 7 marks)

131. A solar cell is a device that generates a potential difference when certain wavelengths of the electromagnetic spectrum are incident on it.

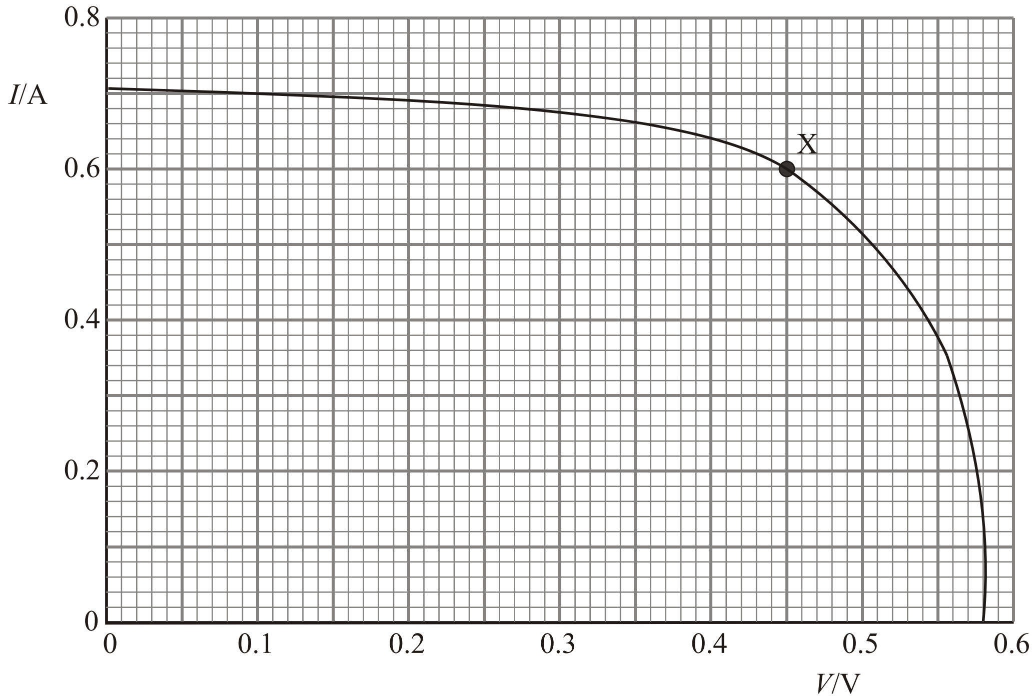
The circuit symbol for a solar cell is



The solar cell is used in a circuit with a variable resistor, an ammeter and a voltmeter. Readings of current *I* in the circuit and the terminal potential difference *V* across the solar cell are used to plot a graph of *I* against *V*. Draw a suitable circuit diagram.

(2)

The graph shows a set of results obtained in this way. The intensity of the light incident on the cell remained constant while the readings were obtained.



Calculate the power output of the cell at the point marked X on the graph.

....

....

Power = ...

(2)

Describe the variation of the power output of the cell as the current increases from zero to its maximum value.

....

....

....

....

....

....

(3)

State the e.m.f. of the cell.

....

(1)

Calculate the internal resistance of the cell when it is operating under the conditions represented by point X.

………………………………………………………………………………………………………

………………………………………………………………………………………………………

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Internal resistance = ...

(2)

(Total 10 marks)

132. Tick whether the following statements are true or false. In each case explain your reasoning.

Statement 1

When a battery is connected across a thick wire in series with a thin wire of the same material, the electrons move faster through the thick wire.

True ☐ False ☐

Explanation

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………………………………………………………………………………………………………

(3)

Statement 2

When a battery is connected across a high resistance in parallel with a low resistance, more power is dissipated in the low resistance.

True ☐ False ☐

Explanation

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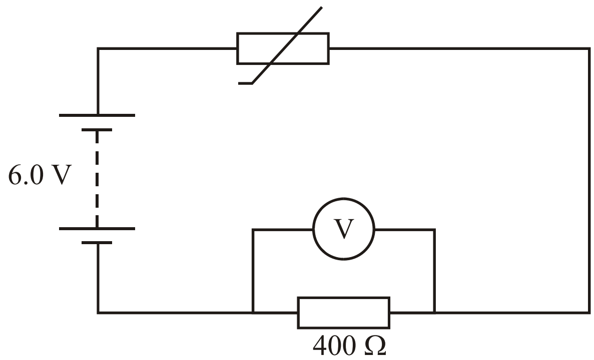
(3)

(Total 6 marks)

133. A student connects the circuit as shown in the diagram.



The reading on the voltmeter is 1.8 V. Calculate the current in the resistor.

……………………………………………………………………………………………

……………………………………………………………………………………………

Current = ...

(1)

Calculate the resistance of the thermistor.

……………………………………………………………………………………………….

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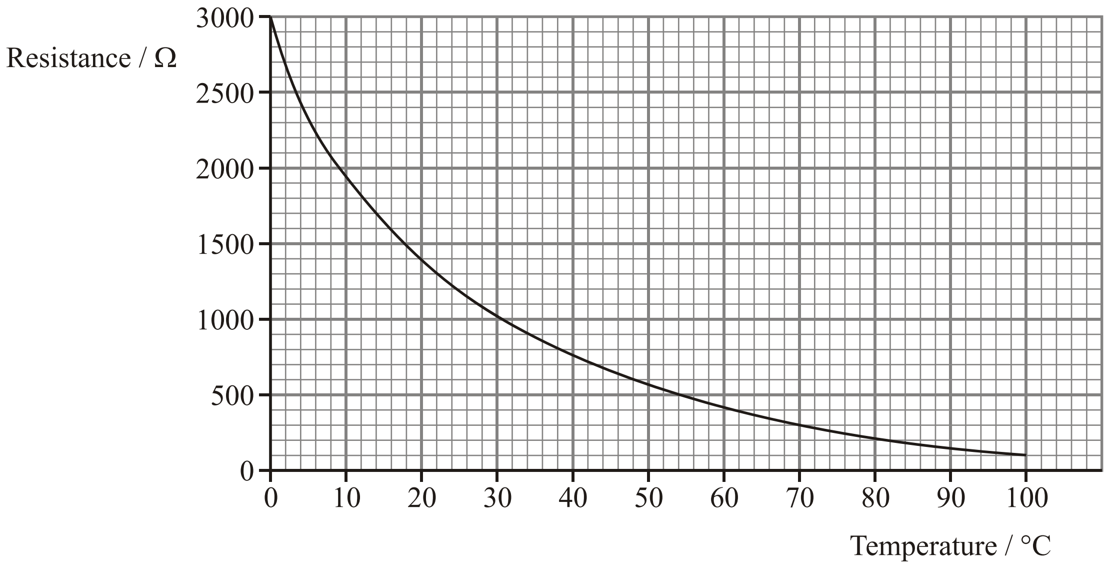
……………………………………………………………………………………………….

Resistance = ...

(2)

The graph shows how the resistance of the thermistor depends on its temperature.



Determine the temperature of the thermistor.

Temperature = ...

(1)

If the e.m.f. of the supply were doubled, would the reading on the voltmeter double?

Explain your answer.

……………………………………………………………………………………………….

……………………………………………………………………………………………….

……………………………………………………………………………………………….

……………………………………………………………………………………………….

(3)
(Total 7 marks)

134. Define the term **specific latent heat of fusion**.

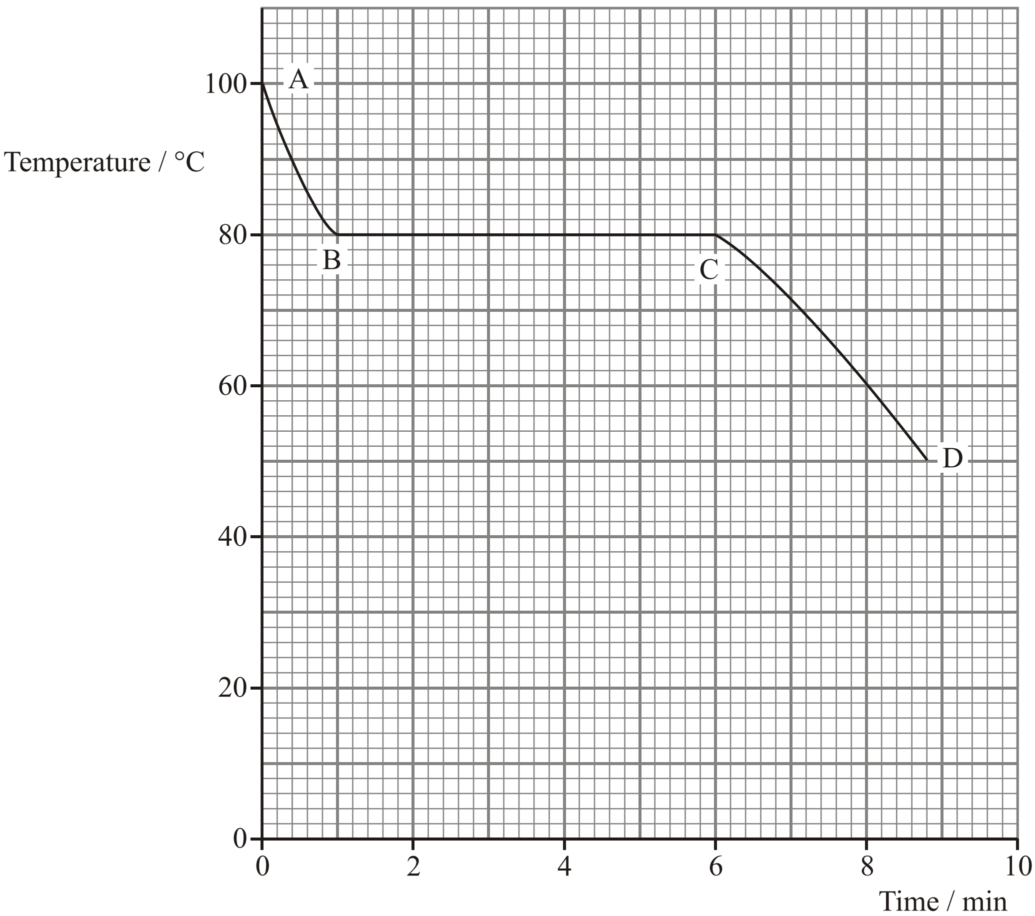
……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

(3)

A cooling curve for an organic substance, which is initially a liquid, is shown below.



State what is happening during each section of the graph.

AB ……………………………………………………………………………………………

BC ……………………………………………………………………………………………

……………………………………………………………………………………………………

CD ……………………………………………………………………………………………

(4)

The specific heat capacity of the substance in its liquid state is 2100 J kg^{-1} K^{-1}. Calculate the energy given out by 0.500 kg of the substance when the temperature falls by 20 °C.

………………………………………………………………………………………………….

………………………………………………………………………………………………….

………………………………………………………………………………………………….

Energy = ...

(2)

The total energy given out by this mass between points A and C on the graph is 106 000 J. Calculate the specific latent heat of fusion of this substance.

………………………………………………………………………………………………….

………………………………………………………………………………………………….

………………………………………………………………………………………………….

Specific latent heat = ...

(3)
(Total 12 marks)

135. A student is asked to carry out an experiment to find the resistivity of the material of a length of resistance wire. Draw an appropriate circuit diagram.

(2)

List all the measurements the student should take to find the resistivity.

………………………………………………………………………………………………….

………………………………………………………………………………………………….

………………………………………………………………………………………………….

………………………………………………………………………………………………….

(3)

How should these measurements be used to find the resistivity?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(3)

Suggest two precautions the student should take to ensure an accurate result.

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(2)
(Total 10 marks)

136. All hydraulic systems use the same physical principles. Explain how large forces can be produced from relatively small forces in such systems. You may be awarded a mark for the clarity of your answer.

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(Total 4 marks)

137. Modern electric showers need to be very powerful because they are required to heat the water flowing through them very quickly.

(a) A typical flow rate of water through a shower is 75 g s^{-1} when the water is being heated through a temperature rise of 30 °C.

The specific heat capacity of water is 4200 J kg^{-1} K^{-1}. Show that the shower provides thermal energy at a rate of approximately 9 kW.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

(3)

The shower operates at a voltage of 230 V. Calculate the current necessary to provide a power of 9 kW.

……………………………………………………………………………………………

……………………………………………………………………………………………

Current = ...

(2)

(b) The shower is connected to the electrical supply by a copper cable 15 m long. A conductor inside the cable has a cross-sectional area of 6.0×10^{-6} m^2. The resistivity of copper is 1.7×10^{-8} Ω m. Find the resistance of the conductor.

……………………………………………………………………………………………

……………………………………………………………………………………………

Resistance = ...

(3)

The conductors used for most electrical circuits in homes are copper but they have a smaller cross-sectional area. Suggest why the manufacturer of the shower recommends that the thicker wire is used in the shower cable.

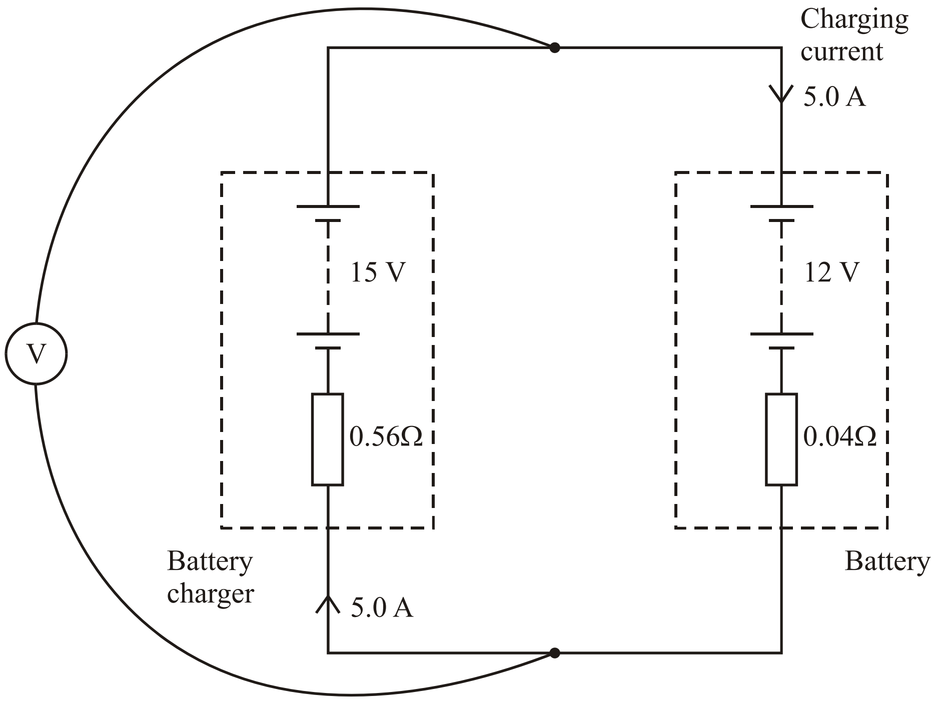
……………………………………………………………………………………………

……………………………………………………………………………………………

(2)

(Total 10 marks)

138. A 12 V car battery is recharged by passing a current of 5.0 A through it in the reverse direction using a 15 V battery charger. The internal resistance of the charger and the battery are 0.56 Ω and 0.04 Ω respectively. The circuit used is shown below.



The terminal p.d. across the battery charger is found by solving the following equation:

$$\text{Terminal p.d.} = 15\text{ V} - (5.0\text{ A} \times 0.56\ \Omega)$$

Determine the reading on the voltmeter.

………………………………………………………………………………………………

(1)

Write an equivalent equation for the terminal p.d. across the battery.

………………………………………………………………………………………………

………………………………………………………………………………………………

(3)

Calculate the rate at which energy is being wasted during the recharging process.

………………………………………………………………………………………………

………………………………………………………………………………………………

Rate = ...

(2)

Hence determine the efficiency of the recharging process.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Efficiency = ...

(2)

The internal resistance of this car battery is 0.04 **Ω**. Explain why a car battery is designed to have a very low internal resistance.

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…………………………………………………………………………………………………

(2)
(Total 10 marks)

139. The kinetic model gives the following formula for the pressure exerted by a gas

$$p = \frac{1}{3}\rho\langle c^2\rangle$$

where the symbols have their usual meanings.

Five gas molecules have speeds of 340 m s^{-1}, 420 m s^{-1}, 670 m s^{-1}, 550 m s^{-1} and 590 m s^{-1}. Calculate the value of $\langle c^2\rangle$ for these molecules.

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…………………………………………………………………………………………………

$\langle c^2\rangle$ = ...

(3)

Write an expression for the density of a gas in terms of the number of molecules *N*, the mass of each molecule *m* and the volume of the gas *V*.

…………………………………………………………………………………………………

(1)

For ideal gases $pV = nRT$.

Show that for a given mass of an ideal gas the mean kinetic energy of a molecule is proportional to the kelvin temperature of the gas.

…………………………………………………………………………………………………

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(3)
(Total 7 marks)

140. (a) Show that the energy stored in a stretched wire below the limit of proportionality can be written $\Delta W = \frac{1}{2} k(\Delta x)^2$ where k is the Hooke's law constant.

…………………………………………………………………………………………

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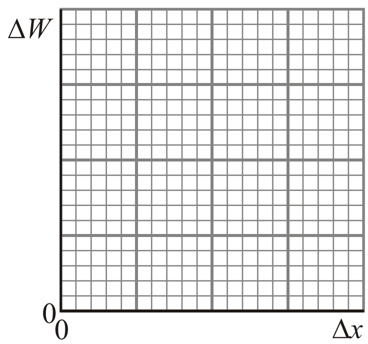
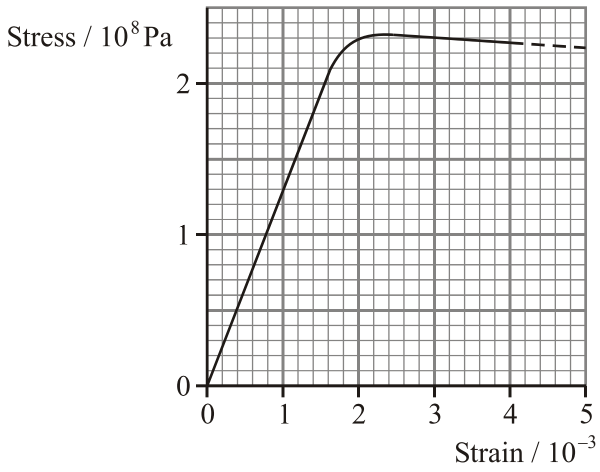
(2)

On the axes below sketch a graph showing how energy stored ΔW varies with extension Δx of a wire below its elastic limit.



(2)

(b) The graph shows the stress-strain relationship for copper.



Use the graph to determine the Young modulus of copper.

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(4)

A student is measuring the extension of a copper wire for a number of forces. Why should a long wire be used in this experiment?

…………………………………………………………………………………………

…………………………………………………………………………………………

(1)

The wire has a radius of 7.1×10^{-4} m. Calculate the stress produced when the wire is stretched by a force of 280 N.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

(3)

Mark this point on the stress-strain graph. Label it P.

(1)

Is the behaviour of the wire at this stress likely to be elastic or plastic? Justify your answer.

…………………………………………………………………………………………

…………………………………………………………………………………………

(1)

(c) Explain with the aid of a **single** diagram what is meant by an edge dislocation.

…………………………………………………………………………………………

………………………………………………………………………………………… **(2)**

Describe how the presence of dislocations can reduce the risk of metals failing by cracking. You may be awarded a mark for the clarity of your answer.

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…………………………………………………………………………………………

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…………………………………………………………………………………………

………………………………………………………………………………………… **(4)**

(d) Describe how high density polythene (HDPE), Melamine and Perspex behave on heating.

HDPE ....

Melamine ....

Perspex .... **(3)**

Suggest a typical use for each polymer.

HDPE ....

Melamine ....

Perspex .... **(3)**

(e) Describe the difference between the processes of annealing and quench-hardening.

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……………………………………………………………………………………………

……………………………………………………………………………………………

(2)

Suggest an item that could be made from quench-hardened steel.

……………………………………………………………………………………………

(1)

(f) Explain why a pre-stressed reinforced concrete beam is more appropriate than a simple concrete beam to bridge a gap.

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……………………………………………………………………………………………

(3)
(Total 32 marks)

141. Below is a list of words associated with circuits.

Current	Volt	Resistance
Ohm	Charge	Ampere

For each of the following choose **one** example from the above list.

Base unit ....

Derived quantity ....

Derived unit...

Base quantity ....

(Total 4 marks)

142. Io is one of Jupiter's moons. Some of the electrons released from the volcanic surface of Io have an average velocity of 2.9×10^7m s^{-1} towards Jupiter. The distance between Jupiter and Io is 4.2×10^5 km.

(a) Show that the time taken for these electrons to reach Jupiter is about 14 s.

....

....

(2)

(b) In this way a current of 3.0×10^6 A is created between Io and Jupiter. Calculate the number of electrons that arrive at Jupiter every second.

....

....

....

Number of electrons = ...

(2)

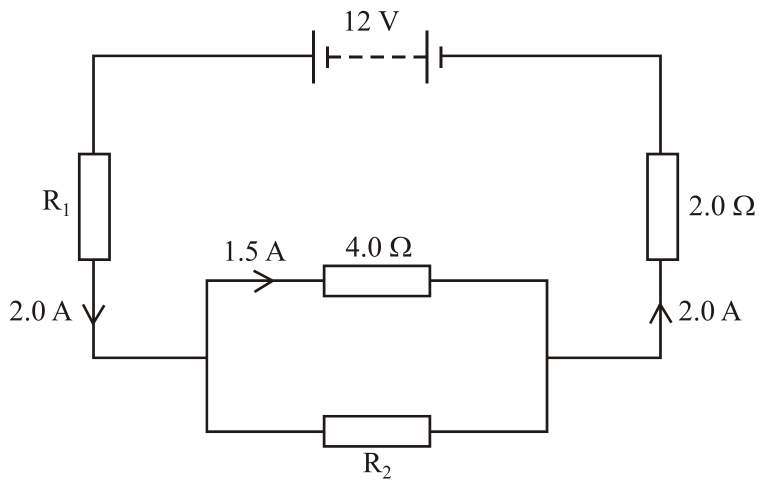
(c) State the direction of the current.

....

(1)

(Total 5 marks)

143. The circuit diagram shows a 12 V d.c. supply of negligible internal resistance connected to an arrangement of resistors. The current at three places in the circuit and the resistance of two of the resistors are given on the diagram.



(a) Calculate the potential difference across the 4.0 Ω resistor.

....

....

Potential difference = ...

(1)

(b) Calculate the resistance of resistor R_2.

....

....

....

Resistance of R_2 = ...

(2)

(c) Calculate the resistance of resistor R_1.

....

....

....

....

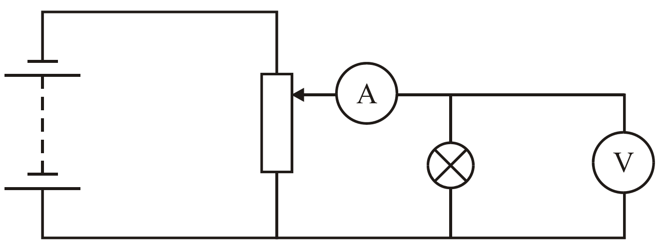
....

Resistance of R_1 = ...

(3)

(Total 6 marks)

144. The circuit shown is used to produce a current-potential difference graph for a 12 V, 24 W filament lamp.



(a) Calculate the current in the filament lamp when the potential difference across it is 12 V.

....

....

Current = ...

(2)

(b) (i) Sketch a graph of current against potential difference for this filament lamp.

(2)

(ii) Explain, with reference to the filament, the shape of your graph, as the potential difference across the filament increases from 0 V to 12 V.

....

....

....

....

....

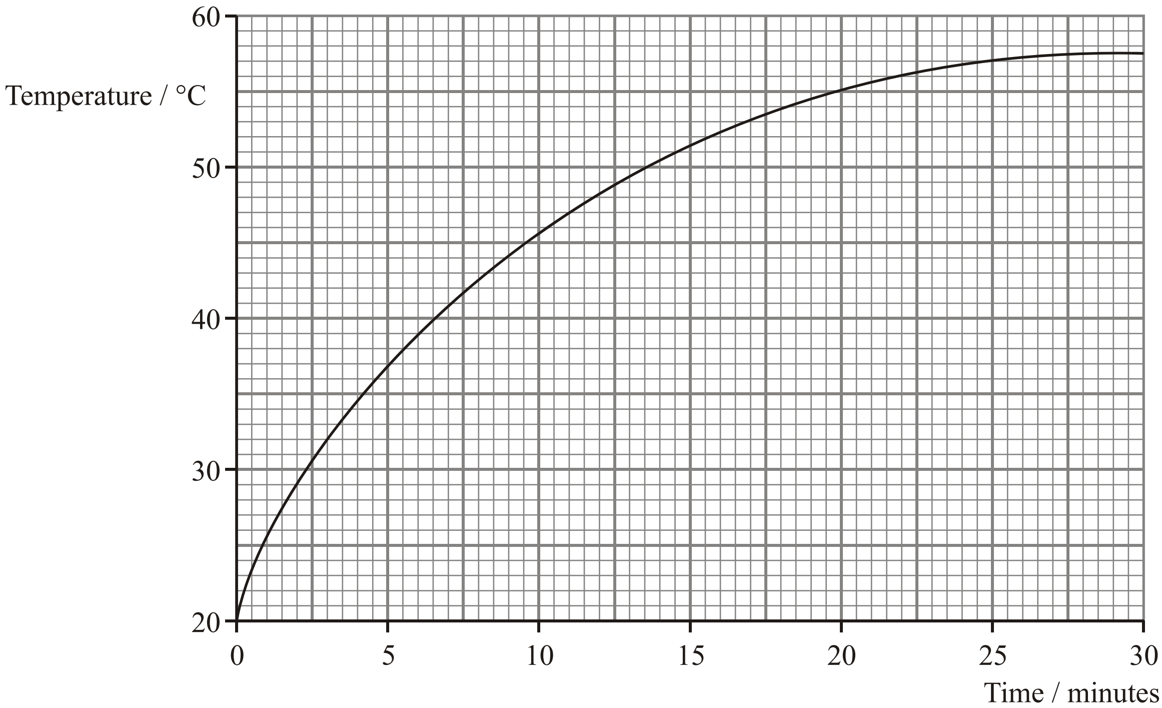
....

....

....

(4)
(Total 8 marks)

145. A small electrical heater, operating at a constant power, was used to heat 64 g of water in a thin plastic cup. The mass of the cup was negligible. The temperature of the water was recorded at regular intervals for 30 minutes and a graph drawn of temperature against time.



(a) (i) Use the graph to determine the initial rate of temperature rise of the water.

....

....

Rate of temperature rise = ...

(2)

(ii) The specific heat capacity of water is 4200 J kg^{-1} K^{-1}. Determine the rate at which energy was supplied to the water by the heater.

....

....

....

Rate of energy supply = ...

(3)

(b) After 26 minutes the rate of temperature rise became very small. Explain why.

....

....

....

(2)

(c) The experiment was repeated using the same mass of water in a thick ceramic mug. The initial temperature of the water was the same and the water was heated for the same length of time.

(i) Add to the axes opposite a possible graph of temperature against time for the water in the mug.

(2)

(ii) Explain your reasoning for your graph.

....

....

....

....

(2)

(Total 11 marks)

146. The pressure p of an ideal gas is related to its volume V and temperature T by the ideal gas equation

$$pV = nRT$$

(a) (i) State what is represented by the following symbols.

n ....

R ....

(2)

(ii) What is meant by the absolute zero of temperature?

....

....

(1)

(b) A room has a volume of 60 m^3. On a hot day the air temperature is 25 °C and the air pressure is 1.1×10^5 Pa.

Calculate how many moles of air there are in the room under these conditions. Assume that air behaves as an ideal gas.

....

....

....

....

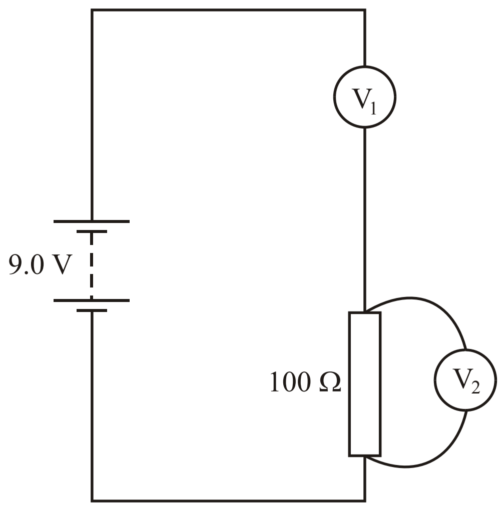
....

....

Number of moles = ...

(3)
(Total 6 marks)

147. (a) A student sets up a circuit and accidentally uses two voltmeters V_1 and V_2 instead of an ammeter and a voltmeter. The circuit is shown below.



(i) Circle the voltmeter which should be an ammeter.

(1)

(ii) Both voltmeters have a resistance of 10 MΩ. The student sees that the reading on V_2 is 0 V. Explain why the potential difference across the 100 Ω resistor is effectively zero.

....

....

....

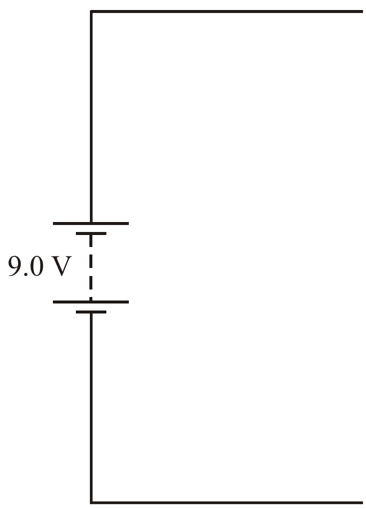
....

(2)

(b) The student replaces the 100 Ω resistor with another resistor of resistance *R*. The reading on V_2 then becomes 3.0 V.

(i) Complete the circuit diagram below to show the equivalent resistor network following this change.

Label the resistor *R*.



(2)

(ii) Calculate the value of R.

....

....

....

....

....

R = ...

(3)

(Total 8 marks)

148. The maximum efficiency of a heat engine is given by

$$\text{Efficiency} = \frac{T_1 - T_2}{T_1}$$

(a) State what is represented by the terms

T_1 ....

T_2 ....

(2)

(b) (i) A modern power station works at an efficiency of 53% and releases steam into the atmosphere at a temperature of 100 °C. Use the formula to calculate the initial temperature of the steam.

....

....

....

....

....

....

Initial temperature = ...

(3)

(ii) In principle, how could the efficiency of this power station be improved?

....

....

....

(1)
(Total 6 marks)

149. Smoke particles suspended in air were illuminated and viewed through a microscope.

(a) Describe what would have been observed. Explain how this experiment gives evidence for the particulate nature of a gas. You may be awarded a mark for the clarity of your answer.

....

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....

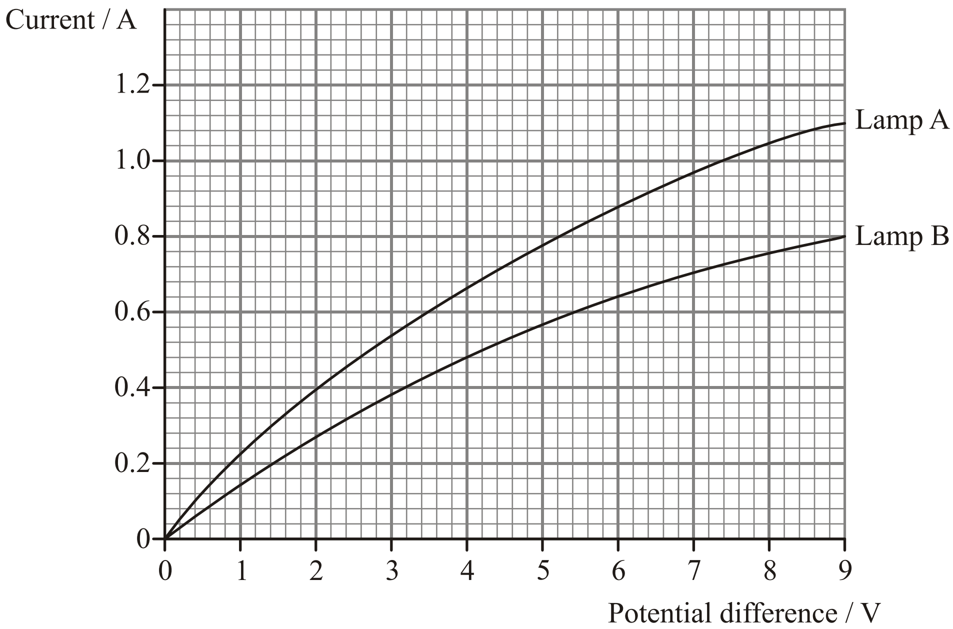
....

(4)

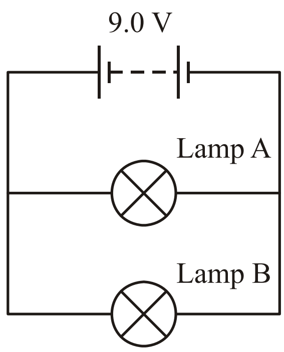
(b) Sketch the possible motion of one smoke particle.

(2)
(Total 6 marks)

150. Two filament lamps are designed to work from a 9.0 V supply but they have different characteristics. The graph shows the current-potential difference relationship for each lamp.



(a) The lamps are connected in parallel with a 9.0 V supply as shown.



(i) Which lamp is brighter? Give a reason for your answer.

....

....

(2)

(ii) Determine the current in the supply.

....

....

Current = ……………………………

(2)

(iii) Calculate the total resistance of the two lamps when they are connected in parallel.

....

....

....

....

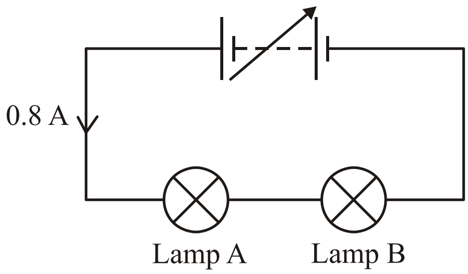
....

....

Total resistance = ...

(2)

(b) The lamps are now connected in **series** to a variable supply which is adjusted until the current is 0.8 A.



Compare and comment on the brightness of the lamps in this circuit.

....

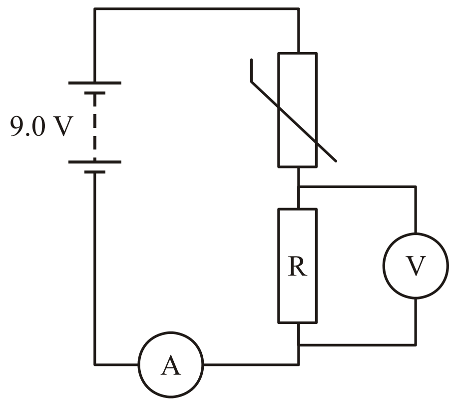
....

....

....

(3)
(Total 9 marks)

151. A student connects a 9.0 V battery in series with a resistor R, a thermistor and a milliammeter. He connects a voltmeter in parallel with the resistor. The reading on the voltmeter is 2.8 V and the reading on the milliammeter is 0.74 mA.



(a) (i) Show that the resistance of R is approximately 4000 Ω.

....

....

(2)

(ii) Calculate the resistance of the thermistor.

....

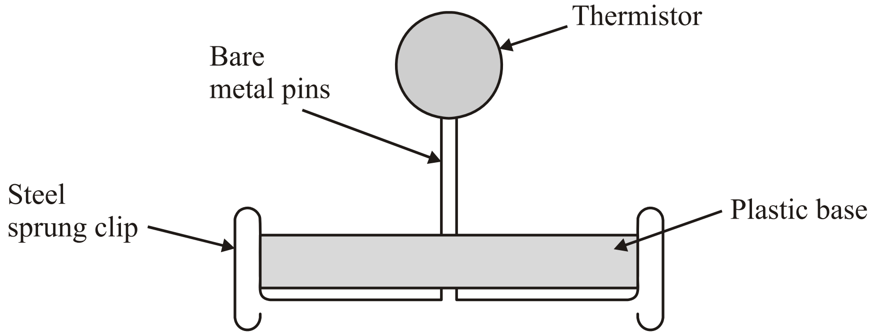
....

....

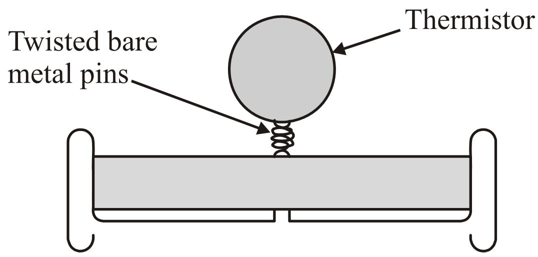
Resistance = ……………………………...

(2)

(b) The thermistor is mounted on a plastic base that has steel sprung clips for secure connection in a circuit board.



Another student is using an identical circuit except that the bare metal pins of his thermistor are twisted together.



Suggest an explanation for how the reading on this student's milliammeter will compare with that of the first student.

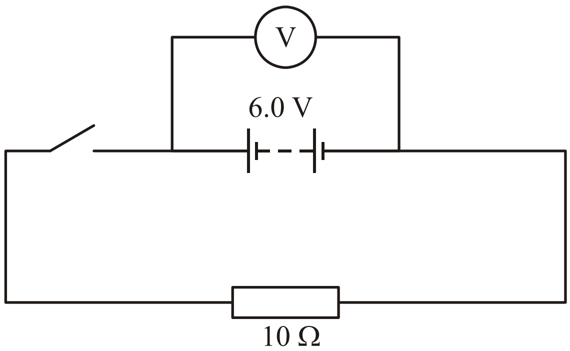
....

....

....

(3)
(Total 7 marks)

152. A battery of e.m.f. 6.0 V is connected to a 10 Ω resistor as shown in the circuit diagram.



(a) Define the e.m.f. of the battery.

....

....

....

(2)

(b) When the switch is open the voltmeter reading is 6.0 V. The internal resistance of the battery is 0.40 Ω. Calculate the reading on the voltmeter when the switch is closed.

....

....

....

....

Voltmeter reading = ...

(3)

(c) A second identical battery is connected in parallel with the first one. Describe and explain qualitatively what would happen to the voltmeter reading if the switch remains closed.

....

....

....

....

....

(3)
(Total 8 marks)

153. (a) A student thinks that the formula for the current I in a conductor of length l is

$$I = \frac{\pi Q v}{l}$$

where Q is the charge on each charge carrier and v is their average drift velocity.
Show whether or not the equation is homogeneous with respect to units.

....

....

....

(2)

(b) Suggest why an equation which is homogeneous with respect to units may **not** be correct.

....

....

(1)

(c) Another equation for the current I is given by the formula

$$I = nAQ\upsilon$$

where A is the cross-sectional area of the conductor.

In this equation what is the unit of n?

....

(1)
(Total 4 marks)

154. (a) Draw a labelled diagram of the apparatus you would use to verify that the pressure exerted by a fixed mass of gas at constant volume is directly proportional to its kelvin temperature.

(4)

(b) State the readings you would take. Explain how you would use your measurements to verify this relationship between pressure and temperature. You may be awarded a mark for the clarity of your answer.

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....

....

(5)

(c) State one precaution that you would take in order to ensure accurate results.

....

(1)
(Total 10 marks)

155. The first law of thermodynamics is represented by the equation $\Delta U = \Delta Q + \Delta W$.

(a) (i) Explain in molecular terms what is meant by the internal energy U of a body.

....

....

....

(2)

(ii) Energy is transferred to a lead block by repeatedly striking it with a hammer. The head of the hammer has a mass of 0.32 kg and it strikes the block with a speed of 13 m s^{-1}. Show that the kinetic energy of the head of the hammer is approximately 30 J.

....

....

(2)

(iii) The lead block has a mass of 0.18 kg. It is struck 10 times. Determine the maximum temperature rise of the block. The specific heat capacity of lead is 130 J kg^{-1} K^{-1}.

....

....

....

....

Temperature rise = ……………………………………..

(3)

(b) Complete the following table to show how the quantities involved in the first law of thermodynamics change, or otherwise, in the case of the hammered lead block.

Symbol	Energy change	+, – or 0
ΔU	Change in internal energy of the lead	+
ΔU		
ΔW		

(4)
(Total 11 marks)

156. (a) (i) The kinetic model of an ideal gas is based on a number of assumptions. State three of them.

1 ....

....

2 ....

....

3 ....

....

(3)

(ii) An ideal gas sample of volume *V* contains *N* molecules, each of mass *m*. Write down an expression for the density ρ of the gas.

....

....

(1)

(iii) The mean square speed of the molecules is (c^2). Write an expression for the average kinetic energy *E* of a molecule.

....

(1)

(b) The average kinetic energy of a molecule is directly proportional to the kelvin temperature *T*, i.e. E = constant × T. The pressure p of an ideal gas is given by the equation

$$p = \frac{1}{3}\rho\langle c^2 \rangle$$

Use this information to show that p is directly proportional to T for a fixed mass of gas at constant volume.

....

....

....

....

....

....

(3)

(c) An aerosol can contains a propellant gas at a pressure of three times atmospheric pressure at a temperature of 20 °C. The aerosol can is able to withstand a maximum pressure of seven times atmospheric pressure. Calculate the temperature at which the can will explode.

....

....

....

....

Temperature = ...

(3)

(Total 11 marks)

157. (a) (i) Write the word equation that defines potential difference.

....

(1)

(ii) The unit of potential difference is the volt. Express the volt in terms of base units only.

....

....

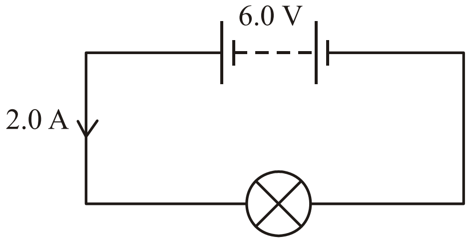
....

....

....

(3)

(b) A 6.0 V battery of negligible internal resistance is connected to a filament lamp. The current in the lamp is 2.0 A.



Calculate how much energy is transferred in the filament when the battery is connected for 2.0 minutes.

....

....

....

....

Energy transferred = ……………………………………

(3)
(Total 7 marks)

158. The current *I* in a conductor of cross-sectional area *A* is given by the formula

$$I = nAQv$$

where *Q* is the charge on a charge carrier.

(a) What quantities do *n* and *v* represent?

n ....

v ....

(2)

(b) A student has a metal conductor and a plastic insulator of the same dimensions. He applies the same potential difference across each. Explain how the relative values of *n* for the metal conductor and plastic insulator affect the current in each.

....

....

....

....

(2)

(c) The student connects two pieces of copper wire, A and B, in series with each other and a battery. The diameter of wire A is twice that of wire B. Calculate the ratio of the drift velocity in wire A to the drift velocity in wire B and explain your answer.

....

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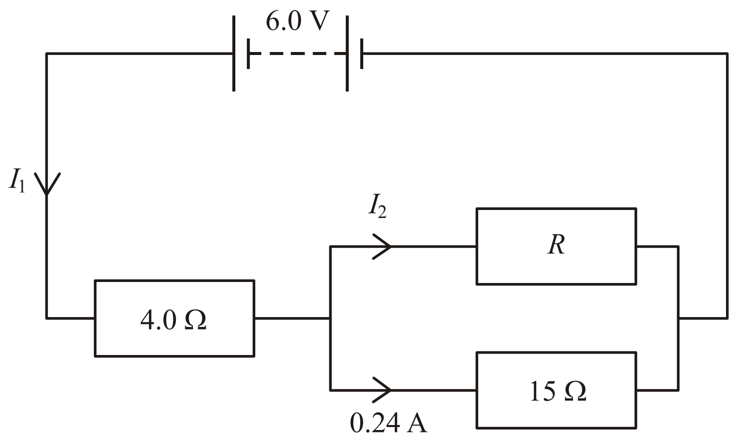
(3)
(Total 7 marks)

159. The circuit shows a battery of negligible internal resistance connected to three resistors.



(a) Calculate the potential difference across the 15 Ω resistor.

....

Potential difference = ...
(1)

(b) Calculate the current I_1 in the 4.0 Ω resistor.

....

....

....

I_1 = ...
(3)

(c) Calculate the current I_2 and the resistance R.

....

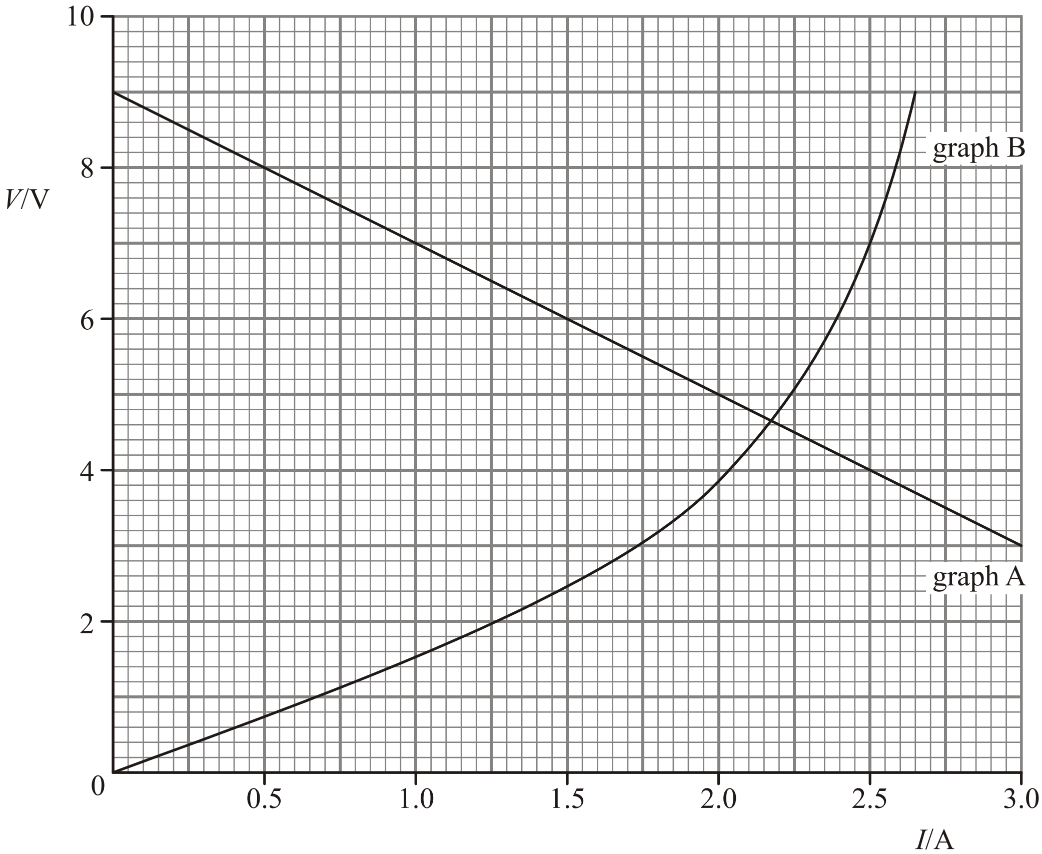
....

....

I_2 = ...

R = ...
(3)
(Total 7 marks)

160. Graph A shows how the potential difference across a battery varies with the current supplied. Graph B shows how the current in a filament lamp varies with the p.d. across it.



(a) (i) Use graph A to determine the internal resistance and the e.m.f. of the battery.

....

....

Internal resistance = ……………………………………

e.m.f = ……………………………………

(2)

(ii) The lamp is connected to the battery. Determine the current in the lamp.

....

(1)

(iii) Calculate the resistance of the filament lamp when it is connected to the battery.

....

....

....

Resistance = ……………………………………

(2)

(b) (i) Draw a diagram of a circuit that would enable graph A to be plotted.

(2)

(ii) Describe how you would use this circuit to obtain the data for the graph.

....

....

....

....

(2)
(Total 9 marks)

161. The equation for an ideal gas is

$$pV = nRT$$

(a) For each of these symbols, state the physical quantity and its S.I. unit. One has been done as an example for you.

Symbol	Physical quantity	S.I. unit
p		
V		
n		
R	Molar gas constant	$\mathrm{J\ K^{-1}\ mol^{-1}}$
T		

(4)

(b) An ideal gas of volume 1.0×10^{-4} m^3 is trapped by a movable piston in a cylinder. The initial temperature of the gas is 20 °C.

The gas is heated and its volume increases by 5.0×10^{-5} m^3 at a constant pressure. Calculate the new temperature of the gas in °C.

....

....

....

....

....

Temperature of gas = ...°C

(4)

(Total 8 marks)

162. (a) Define the term **specific latent heat of fusion.**

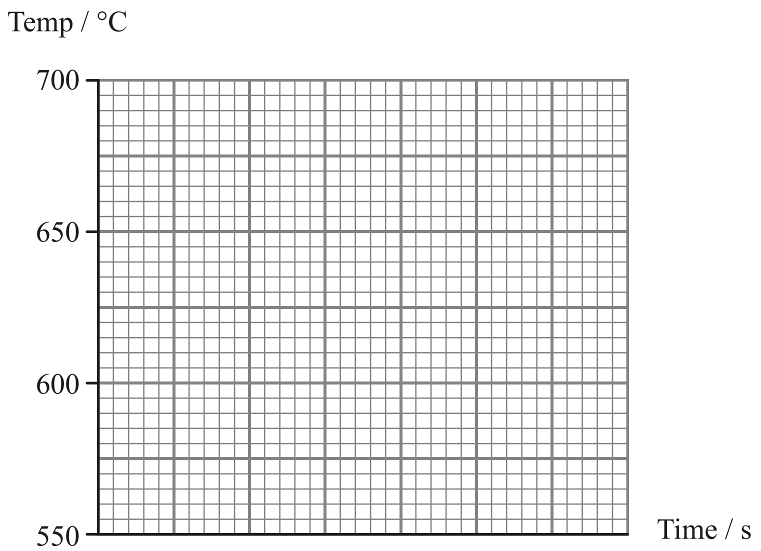
....

....

....

(3)

(b) (i) Aluminium has a melting point of 660 °C. A sample of aluminium at 600 °C is heated steadily until its temperature reaches 700 °C. Sketch a graph to show how the temperature of the aluminium varies with time.



(3)

(ii) Explain the shape of your graph with reference to the potential energy and kinetic energy of the molecules.

....

....

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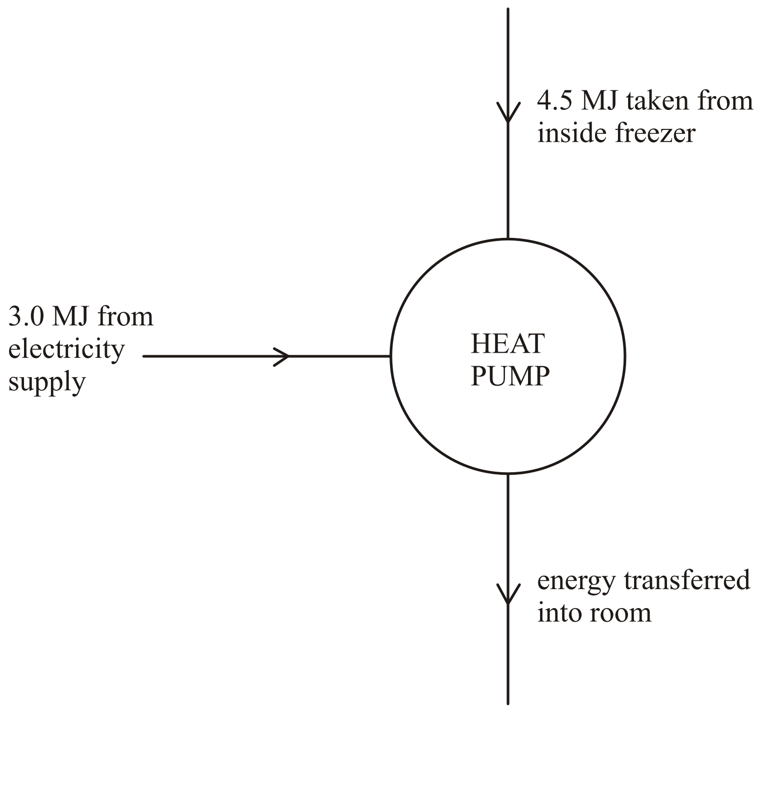
(4)
(Total 10 marks)

163. A freezer contains a heat pump which pumps energy from the inside of the freezer to the outside. The diagram shows the energy flow for one day of use.



(a) (i) How much energy is transferred into the room?

....

Energy = ...

What principle have you applied to do this calculation?

....

(2)

(ii) Why do you need an energy source to pump energy from the inside of the freezer to the outside?

....

....

(1)

(iii) Assuming the inside of the freezer remains at a constant temperature, calculate the rate at which energy is flowing in through the walls of the freezer.

....

....

Rate of flow of energy = ...

(2)

(b) An ice cube tray is filled with 0.35 kg of water at 20 °C and placed in the freezer. The specific heat capacity of water is 4.2×10^3 J kg^{-1} K^{-1} and the specific latent heat of fusion of water is 3.3×10^5 J kg^{-1}. Calculate the minimum amount of additional energy the heat pump has to pump out of the freezer in order to freeze the water.

....

....

....

....

....

....

Energy = ...

(3)

(c) Inside the freezer there are cooling fins towards the top but not at the bottom. Explain how these fins cool the air in the freezer and why there are no fins at the bottom. You may be awarded a mark for the clarity of your answer.

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(4)
(Total 12 marks)